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RESIDUAL STRENGTH TESTS, PARAITINGA AND PARAIBUNA DAMS, BRAZIL.(U)
JUN 74 F C TOWNSEND, P A GILBERT

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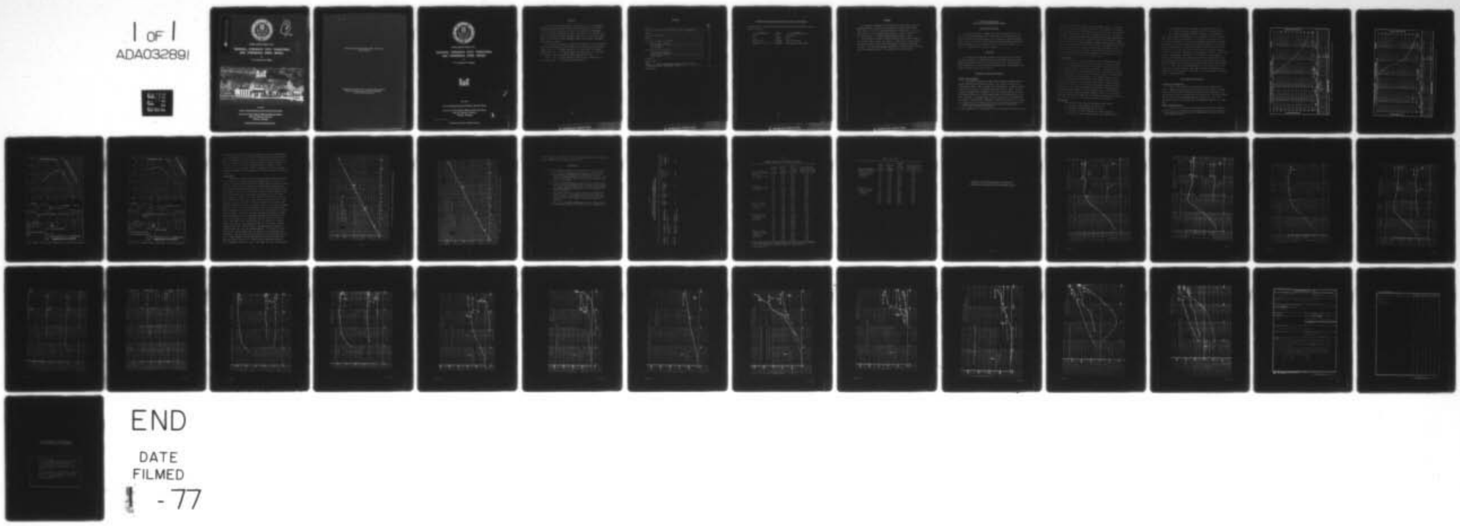

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MISCELLANEOUS PAPER S-74-21

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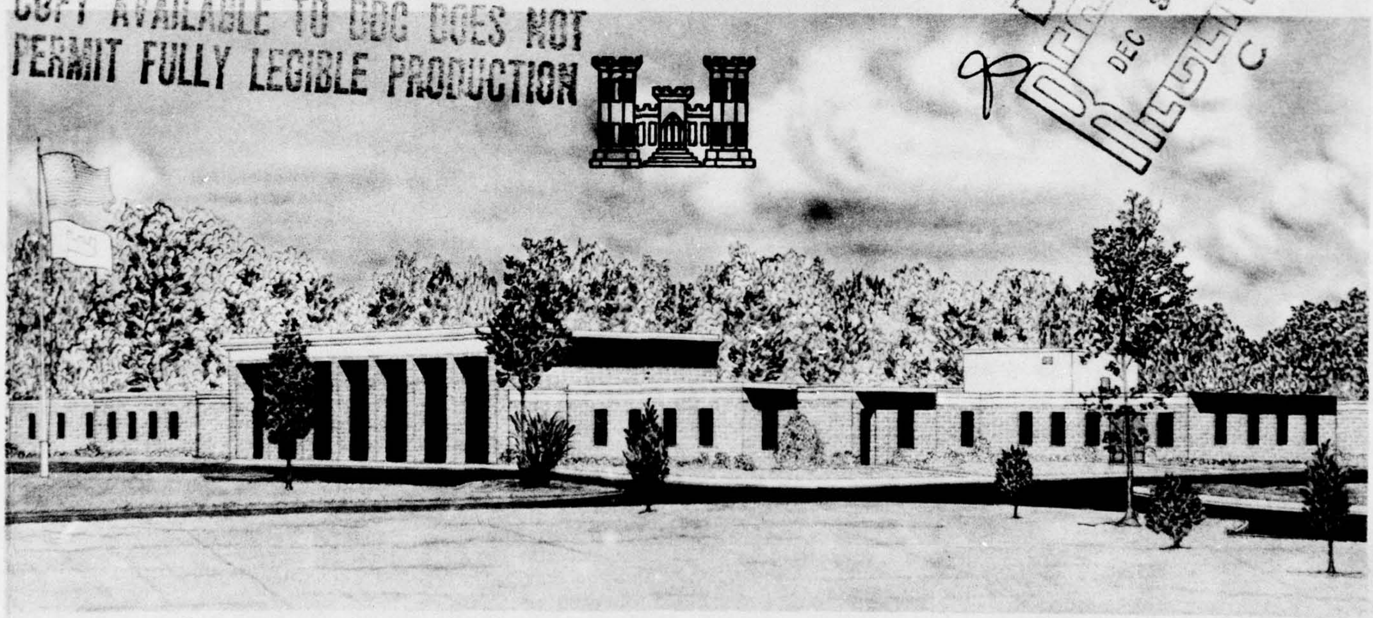
by

F. C. Townsend, P. A. Gilbert



June 1974

Sponsored by Centrais Electrias de Sao Paulo, Sao Paulo, Brazil

Conducted by U. S. Army Engineer Waterways Experiment Station
Soils and Pavements Laboratory
Vicksburg, Mississippi

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ARMY-MRC VICKSBURG MISS

Foreword

The tests reported herein were conducted by the U. S. Army Engineer Waterways Experiment Station (WES) for Centrais Electrias de Saõ Paulo (CESP), Saõ Paulo, Brazil, at the request of Professor A. Casagrande, Harvard University, consultant to CESP. Authorization for the tests was granted in WESSE letter dated 10 August 1973 in response to CESP's request letter of 24 July 1973 and a subsequent CESP telegram dated 4 September 1973 agreeing to terms.

The tests were conducted and the report prepared in the Soils Research Facility, Soil Mechanics Division (SMD), Soils and Pavements Laboratory (S&PL), by Dr. F. C. Townsend and Mr. P. A. Gilbert under the general supervision of Mr. C. L. McAnear, Chief, SMD, and Messrs. J. P. Sale and R. G. Ahlvin, Chief and Assistant Chief, respectively, S&PL.

COL G. H. Hilt, CE, was Director of WES during the preparation of this report. Mr. F. R. Brown was Technical Director.

Contents

Conversion Factors, British to Metric Units of Measurement

British units of measurement used in this report can be converted to metric units as follows:

Multiply	By	To Obtain
inches	2.54	centimeters
feet	0.3048	meters
cubic inches	16.387064	cubic centimeters
pounds per cubic foot	16.018489	kilograms per cubic meter

Summary

The residual strengths of two micaceous soils from Paraitinga and Paraibuna damsites, Brazil, were determined using multistage annular shear tests. Tests were conducted under three normal loads, 1.1, 3.1, and 9.1 kg/cm^2. Test specimens were densely or loosely compacted (i.e., 100 and 90 percent of maximum standard density) prior to shear.

Test results show that the initial specimen density has no effect on the residual shear strength ϕ'_r values. In the case of both materials, ϕ'_r was practically equal for both the densely and loosely compacted specimens. The Paraitinga material exhibited a slightly higher ϕ'_r value than the Paraibuna material, 28.0 versus 26.7 deg, respectively.

Residual Strength Tests
Paraitinga and Paraibuna Dams, Brazil

Introduction and Scope

1. Monotonic residual strength tests were conducted by the U. S. Army Engineer Waterways Experiment Station (WES) on micaceous material from Paraitinga and Paraibuna Dams. The test program consisted of multistage annular shear tests on both loosely and densely compacted specimens from both dams under normal stresses of 1.1, 3.1, and 9.1 kg/cm^2. In addition, classification tests were conducted.

Materials

2. Materials furnished WES included two bag samples (2000 g each) provided by Professor A. Casagrande and two undisturbed block (15-in.^{3}*) samples transported to WES by Mr. Decio Bezerra, CESP. The Paraitinga block sample was from station 8+68, el 639.42,** while the Paraibuna block sample was from station 3+20, el 706.91.

Equipment and Testing Procedures

Annular shear equipment

3. Multistage annular shear tests were conducted using the WES low-capacity annular shear apparatus (LCASA). This 3-position device was constructed at WES in 1967. Annular test specimens have a 4.00-in. outside diameter and a 2.04-in. inside diameter and are 0.75 in. thick. Normal stresses are applied by a pneumatic stress cell mounted beneath the device which applies tension to a cable bearing against the loading platen on top of the specimen. A maximum normal stress of 15 kg/cm^2 can be applied by this method. Shear stresses (maximum 2.5 kg/cm^2) are measured by a torque

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* A table of factors for converting British units of measurement to metric units is presented on page vii.

** All elevations (el) cited herein are in feet referred to mean sea level.

plate through torque arms mounted on the top loading platen. An electrical motor and gear box rotate the lower half of the specimen at displacement rates which can be varied from 170 to 0.34 in. per day. The specimen is confined between upper and lower confining rings, and the gap between rings can be adjusted by screws as the specimen consolidates during shear. Due to the high shear stresses required to achieve the residual strength of these materials, the maximum normal load which could be applied without overstressing the torque arms was 3 to 5 kg/cm^2. Nevertheless, one of the LCASA units was modified to permit higher normal loads, which are reflected in some of the test results. This modification consisted of fabricating a torque plate which could accommodate a miniature load cell instead of torque arms to measure the shear stresses.

Test procedures

4. Upon receipt of the block samples, x-ray radiographs were taken to assist in locating suitable material from which to trim undisturbed specimens. The Paraitinga material had a slight continuous horizontal crack through the sample. This area was avoided. The Paraibuna material was quite homogeneous. Density and water content determinations were made on the block samples using the Hvorslev miniature sampler. Harvard miniature compaction tests were conducted on the trimming scraps of the annular shear specimens prepared from the block samples. These densities were used to compute 90 and 100 percent of the maximum standard density, which were the densities for the loosely and densely compacted specimens, respectively. The compacted specimens were prepared by compacting the required weight of material into the confining rings of the unit using a pneumatic hand-held tamping miniature compactor (similar to the spring-loaded Harvard miniature compactor). All compacted specimens were 0.75 in. high, thus providing a constant volume for density calculations.

Test program

5. Seven annular shear tests were conducted, specifically:

a. Paraitinga (undisturbed block, 94.7 pcf).

b. Paraibuna (undisturbed block, 100.9 pcf).

c. Paraitinga (loosely compacted, 95.5 pcf, bag sample).

d. Paraitinga (loosely compacted, 96.1 pcf, remolded block).

$\underline{e}$. Paraibuna (loosely compacted, 98.0 pcf, remolded block).

$\underline{f}$. Paraitinga (densely compacted, 106.8 pcf, remolded block).

$\underline{g}$. Paraibuna (densely compacted, 108.9 pcf, remolded block).

After the specimens were prepared, they were allowed to swell or consolidate under an initial normal stress of 1.1 kg/cm^2 for specimens d-g or 3.1 kg/cm^2 for specimens a and b until equilibrium was achieved; however, specimen c was consolidated under 3.1 kg/cm^2 and rebounded to 1.1 kg/cm^2 prior to initial shear. Shear was then initiated at a slow rate of displacement* (1.75 cm per day) until peak strength had been well defined (usually after several centimeters of displacement). The rate of displacement was subsequently increased to 7.02 cm per day until an apparent residual shear strength ϕ'_r condition was reached, and then the rate of displacement was reduced to its original value. This method of alternating displacement rates provided a less time-consuming method for determining ϕ'_r. After ϕ'_r had been determined, the next normal stress of the multistage loading was applied, shear was initiated after achieving an equilibrium condition under the new normal stress, and finally the highest normal stress was applied.

Test Results and Discussion

Classification properties

6. Figs. 1 and 2 present the classification test results, and table 1 summarizes the physical properties of the block samples. There was very little difference between the classification properties of the two materials; both are classified as silty sands (SM). The most striking classification difference between the two materials is color: the Paraitinga material is dark red, while the Paraibuna material is a light gray.

Density characteristics

7. Figs. 3 and 4 present the density-water content relationships

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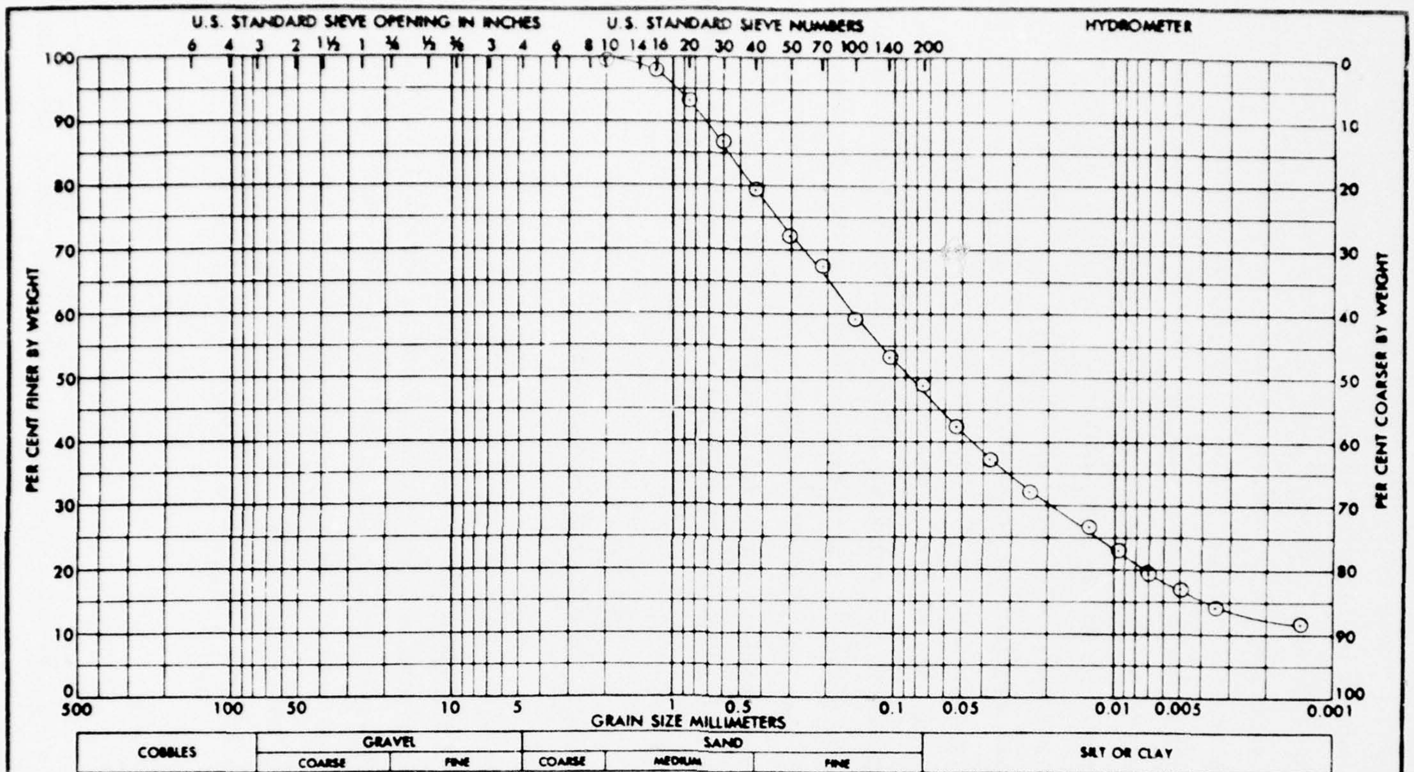
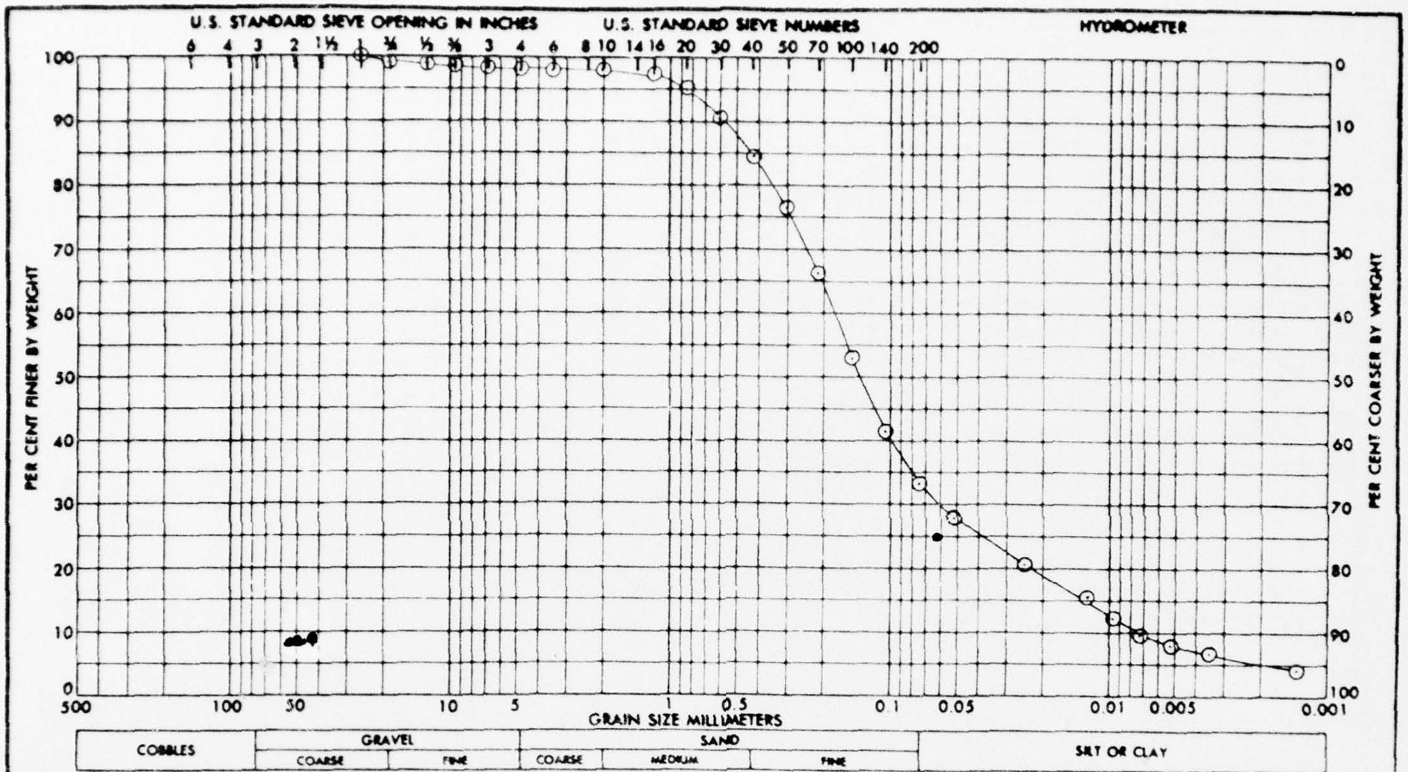
* Displacement is measured along the circumference calculated from the mean specimen diameter.



SAMPLE NO	ELEV OR DEPTH	CLASSIFICATION	NAT W%	LL	PL	PI	PROJECT ALTO RIO PARIABA
		SILTY SAND(SM)		39	28	11	
		Brownish Red					AREA 13
		2.70					BORING NO Obra paraitinga
GRADATION CURVES							DATE 10 Sept. 1973

Fig. 1. Classification and gradation of the Paraitinga Dam material

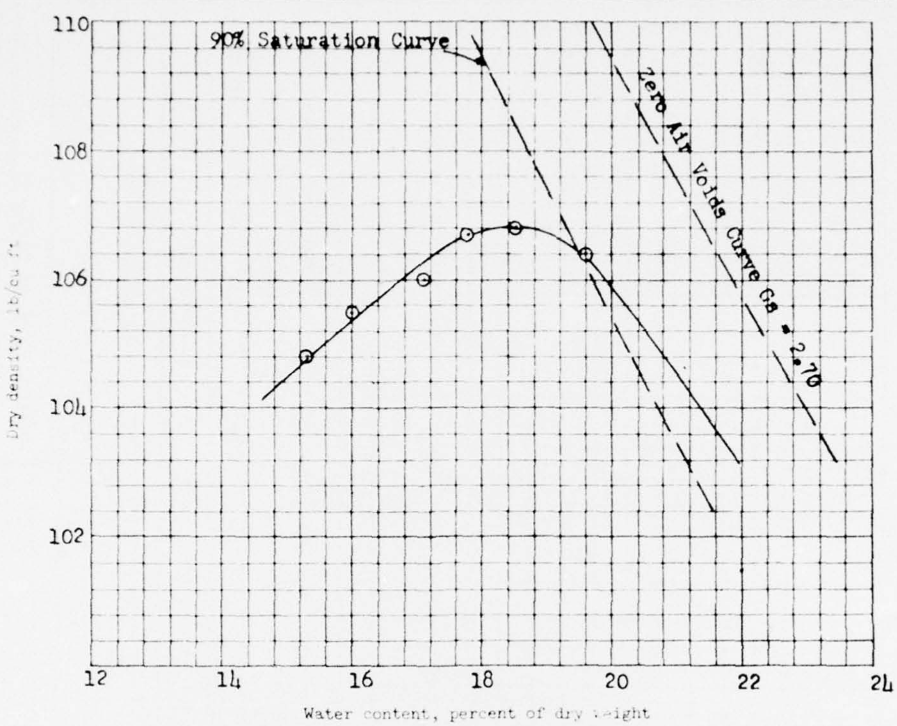


SAMPLE NO	ELEV OR DEPTH	CLASSIFICATION	NAT W%	LL	PL	PI
		SILTY SAND(SM)		33	27	6
		Brown				
		Gs= 2.71				
		With Mica				

GRADATION CURVES

PROJECT	ALTO RIO PARIABA
AREA	E
BORING NO	Obra paraibuna
DATE	10 Sept. 1973

Fig. 2. Classification and gradation of Paraibuna Dam material



HARVARD compaction test

10 blows per each of 5 layers, with 40(Spring) lb rammer and

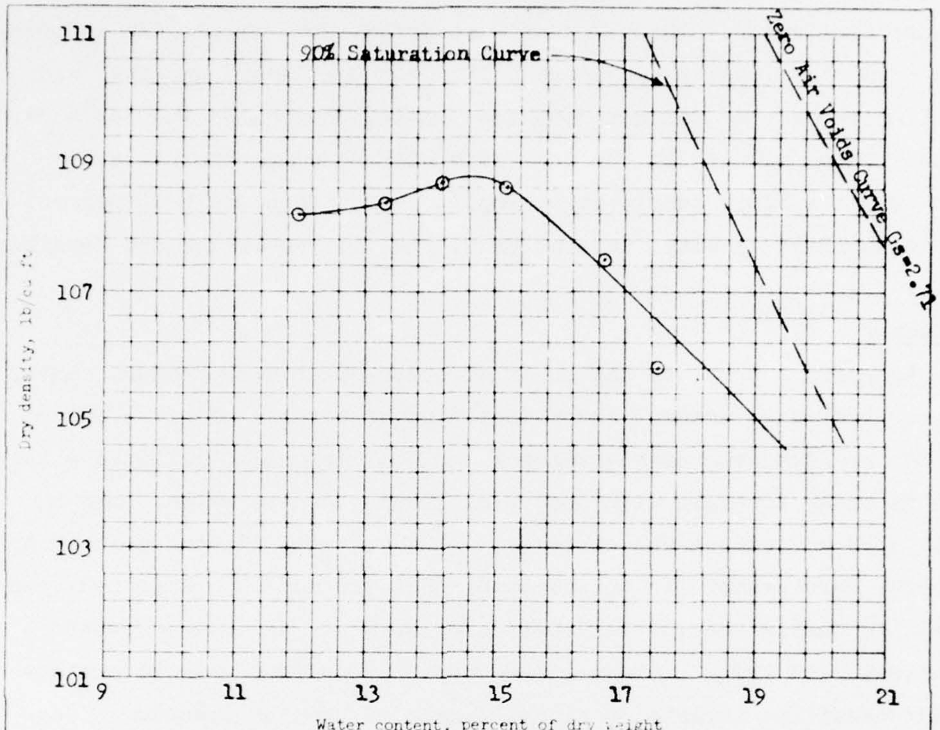
- inch drop. 1.3125 inch diameter mold

Sample No.	Elev or Depth	Classification	G	LL	PL	% > No. 4	% > 3/4 in.
-		SILTY SAND (SM), brownish red	2.70	39	28		

Sample No.				
Natural water content, percent	15.6			
Optimum water content, percent	18.4			
Max dry density, lb/cu ft	106.8			

Remarks	Project ALTO RIO PARIABA	
Sta. 8+68, Elev. 639.42		
Siltao	Area 13	
	Boring No. Obra Paraitinga	Date 7 December 1973
	WJH **COMPACTION TEST REPORT**	

Fig. 3. Water content-density relationship for Paraitinga material



HARVARD compaction test

10 blows per each of 5 layers, with 40 (Spring) lb rammer and

- inch drop. 1.3125 inch diameter mold

Sample No.	Elev or Depth	Classification	G	LL	PL	% > No. 4	% > 3/4 in.
-		SILTY SAND (SM), brown with Mica	2.71	33	27		

Sample No.				
Natural water content, percent	13.1			
Optimum water content, percent	14.6			
Max dry density, lb/cu ft	108.8			

Remarks	
Sta. 3+20, Elev. 706.91	Project ALTO RIO PARIABA
Siltosia, micacea, cinza	Area E
	Boring No. Obra paraibuna — Date 7 December 1973
	WJH **COMPACTION TEST REPORT**

Fig. 4. Water content-density relationship for Paraibuna material

of material from the block samples as determined using the Harvard miniature compaction device. These curves were established to provide information for preparing loosely (90 percent of maximum standard density) and densely (100 percent of maximum standard density) compacted annular shear specimens. These results of the Harvard miniature compaction tests indicate that the block sample densities represent 88.6 and 92.6 percent of maximum standard density, respectively, for the Paraitinga and Paraibuna materials.

Annular shear

8. Appendix A presents the shear strength-shear displacement curves and the vertical displacement-shear displacement curves. Figs. 5 and 6 present the residual strength envelopes. Neither material exhibited a large decrease in shear strength with post peak displacements, rather only a minor (if any) difference was observed. The vertical displacement-shear displacement curves show (as anticipated) that the densely compacted specimens dilated during the initial shear displacements under the lowest normal stress, 1.1 kg/cm^2. Hence, the compactive effort used to achieve the higher densities imparted a slight degree of preconsolidation. Conversely, the loosely compacted specimens exhibited only a small dilative tendency, reflecting the smaller compactive effort. The residual strength envelopes for all tests, undisturbed block and loosely and densely compacted remolded block materials, show that ϕ'_r is independent of initial specimen density. Obviously, the large deformations required to achieve residual alter any structure imposed by compaction, and the final void ratio in the failure zone is dependent only upon the effective normal stress. The results also indicate that ϕ'_r is insensitive to normal stress, with only a slight curvature observed in the residual strength envelope at the lower normal stresses. The Paraitinga material had a slightly higher ϕ'_r than the Paraibuna material, 28.0 versus 26.7 deg, respectively. The extremely high ϕ'_r values for these materials are attributed to the small quantities of minus 2-μ sizes (less than 15 percent). Surprisingly, the Paraibuna material has a lower liquid limit, plasticity index, and minus 2-μ content than the Paraitinga material, yet it exhibited a lower ϕ'_r value. This lower ϕ'_r value could possibly

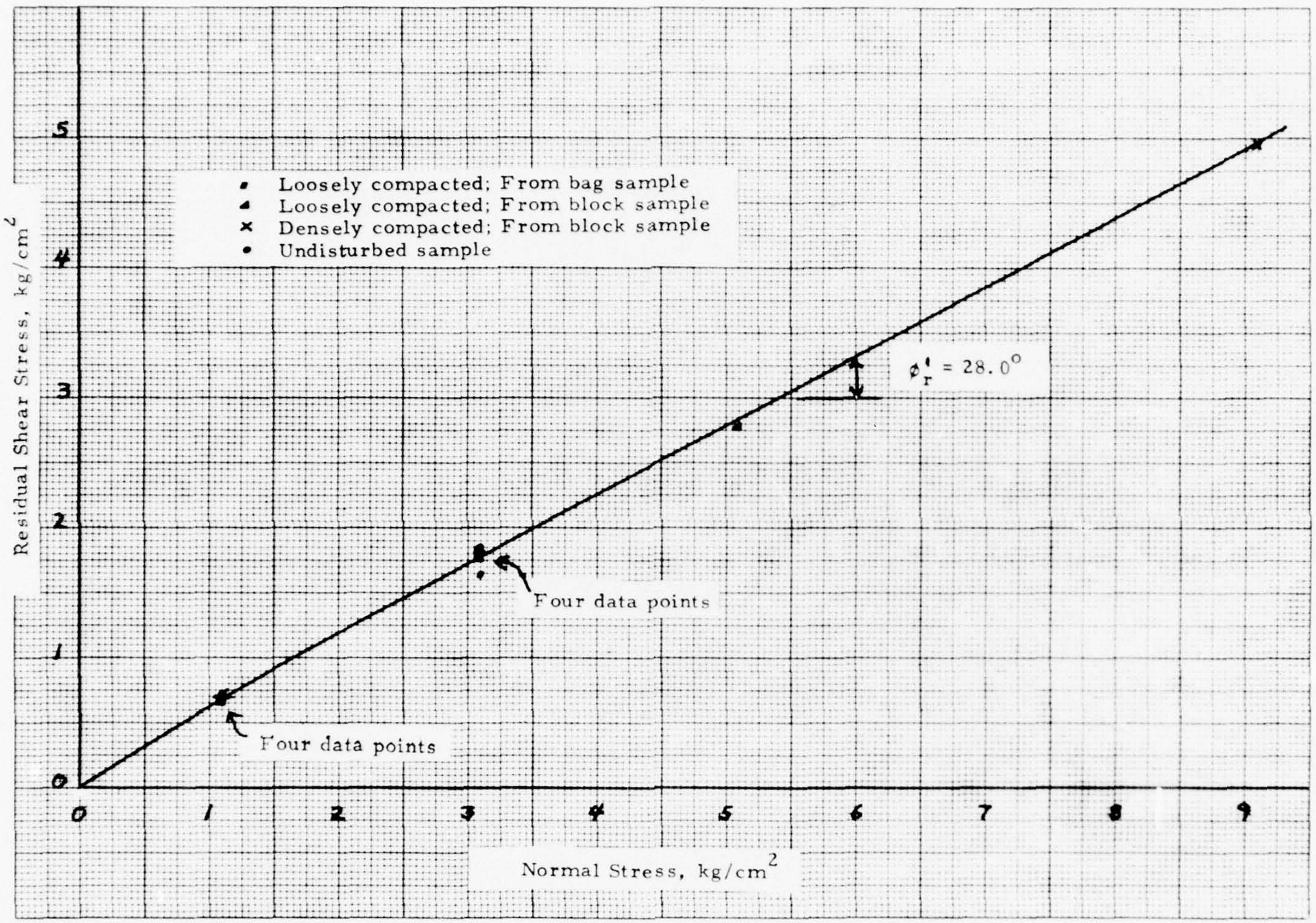


Fig. 5. Residual shear strength envelope for Paraitinga material

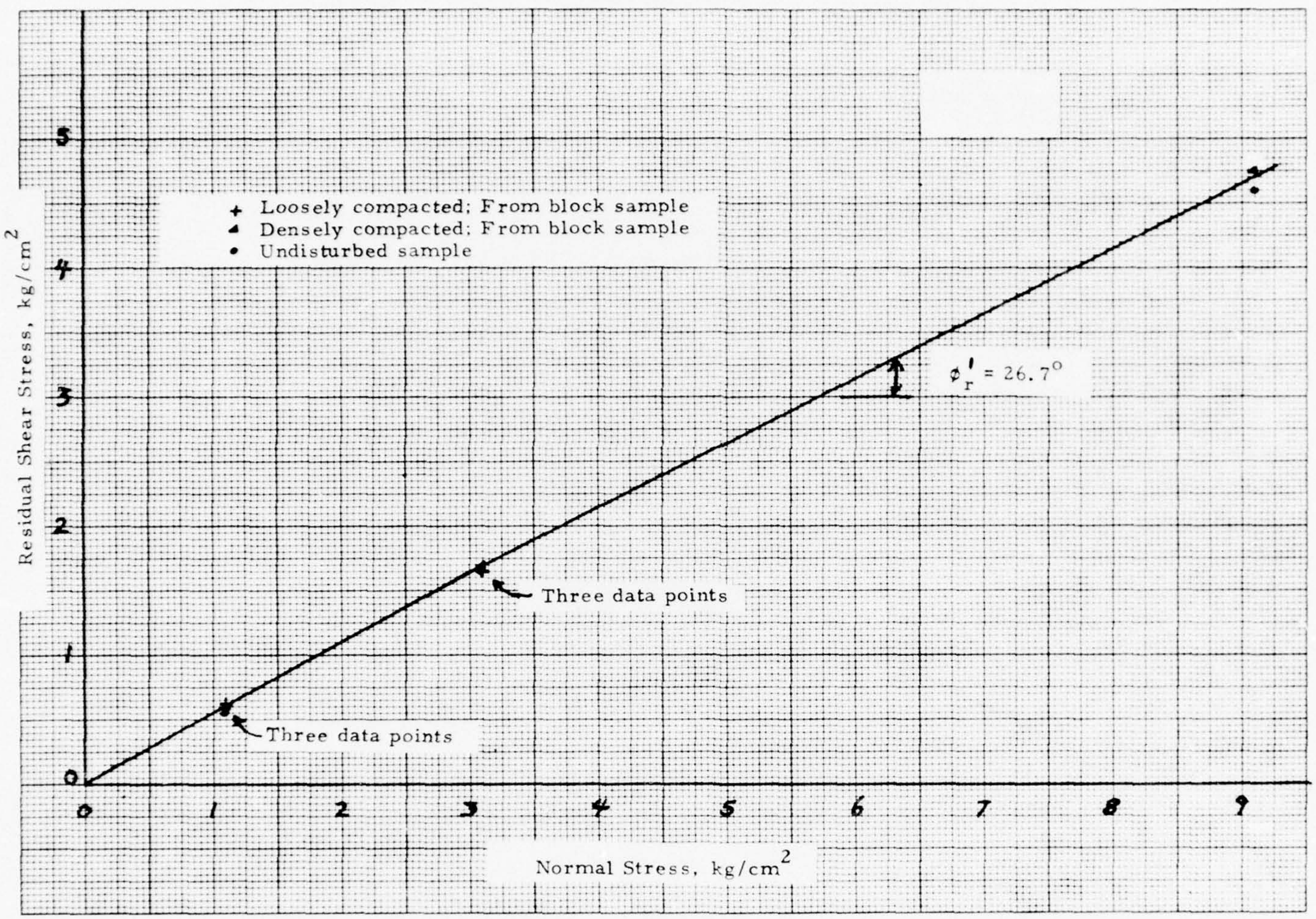


Fig. 6. Residual shear strength envelope for Paraibuna material

be attributed to mineralogical differences (perhaps a higher mica content). Table 2 summarizes the residual strength tests.

Conclusions

9. The following conclusions were drawn based on the test results:

a. The Paraitinga and Paraibuna materials are quite similar; both materials classify as silty sands (SM). The most striking difference between the two materials is color. The Paraitinga material is a deep red, while the Paraibuna mateial is a light gray.

b. Based upon Harvard miniature compaction tests and densities measured using the Hvorslev miniature sampler, the densities of the block samples represent 88.6 and 92.6 percent of maximum standard density, respectively, for the Paraitinga and Paraibuna materials.

c. The residual angle ϕ'_r for this material is independent of initial density. In the case of both materials, the ϕ'_r values for the loosely compacted specimens were practically identical with the ϕ'_r values of the densely compacted specimens.

d. The ϕ'_r for Paraitinga material is slightly higher than that for Paraibuna material, 28.0 versus 26.7 deg, respectively.

Table 1

Physical Properties of Block Samples of
Paraitinga and Paraibuna Dam Embankment Materials

Sample	Location	Identification	Liquid Limit	Plastic Limit	Plasticity Index	Dry Density γ_d, pcf	Water Content w percent
Paraitinga	Station 8+68 el 639.42	Siltaõ	39	28	11	94.7	15.6
Paraibuna	Station 3+20 el 706.91	Siltosia, micacea, cinza	33	27	6	100.9	13.1

Table 2

Summary of Results of Annular Shear Tests

Sample Description	Normal Stress kg/cm^2	Rate of Displacement cm/day	Residual Shear Strength ϕ'_r, deg	Displacement per Stage Required to Achieve ϕ'_r, cm**
Paraitinga, undisturbed block, 94.7 pcf	3.1	1.75	31.3	8.7
	3.1	7.02	31.2	49.8
	3.1	1.75	31.1*	11.7
	1.1	1.75	33.6	9.6
	1.1	7.02	33.1	29.4
	1.1	1.75	32.9*	10.4
Paraibuna, undisturbed block, 100.9 pcf	3.1	1.75	29.5	9.8
	3.1	7.02	28.7	48.7
	3.1	1.75	28.5*	8.5
	1.1	1.75	27.4	9.6
	1.1	7.02	27.8	29.4
	1.1	1.75	27.4*	10.9
	9.1	1.75	28.4	16.1
	9.1	1.02	27.4	51.5
	9.1	1.75	26.7*	16.1
Paraitinga, bag sample, loosely compacted, 95.5 pcf	1.1	1.75	34.5	25.3
	1.1	7.02	33.5	28.1
	1.1	1.75	32.7*	12.3
	3.1	1.75	29.4	19.0
	3.1	7.02	27.8	47.1
	3.1	1.75	27.7*	15.4
Paraitinga, block sample, loosly compacted, 96.1 pcf	1.1	1.75	32.0	17.7
	1.1	7.02	30.8	33.1
	1.1	1.75	31.2*	5.9
	3.1	1.75	30.5	3.8
	3.1	7.02	29.6	48.7
	3.1	1.75	30.0*	2.8
	5.1	1.75	29.5	13.8
	5.1	7.02	28.6	79.9
	5.1	1.75	28.2*	6.4
Paraibuna, block sample, loosely compacted, 98.0 pcf	1.1	1.75	30.1	28.0
	1.1	7.02	29.5	36.8
	1.1	1.75	29.3*	2.7
	3.1	1.75	28.5	13.8
	3.1	7.02	28.0	79.9
	3.1	1.75	26.9*	6.4

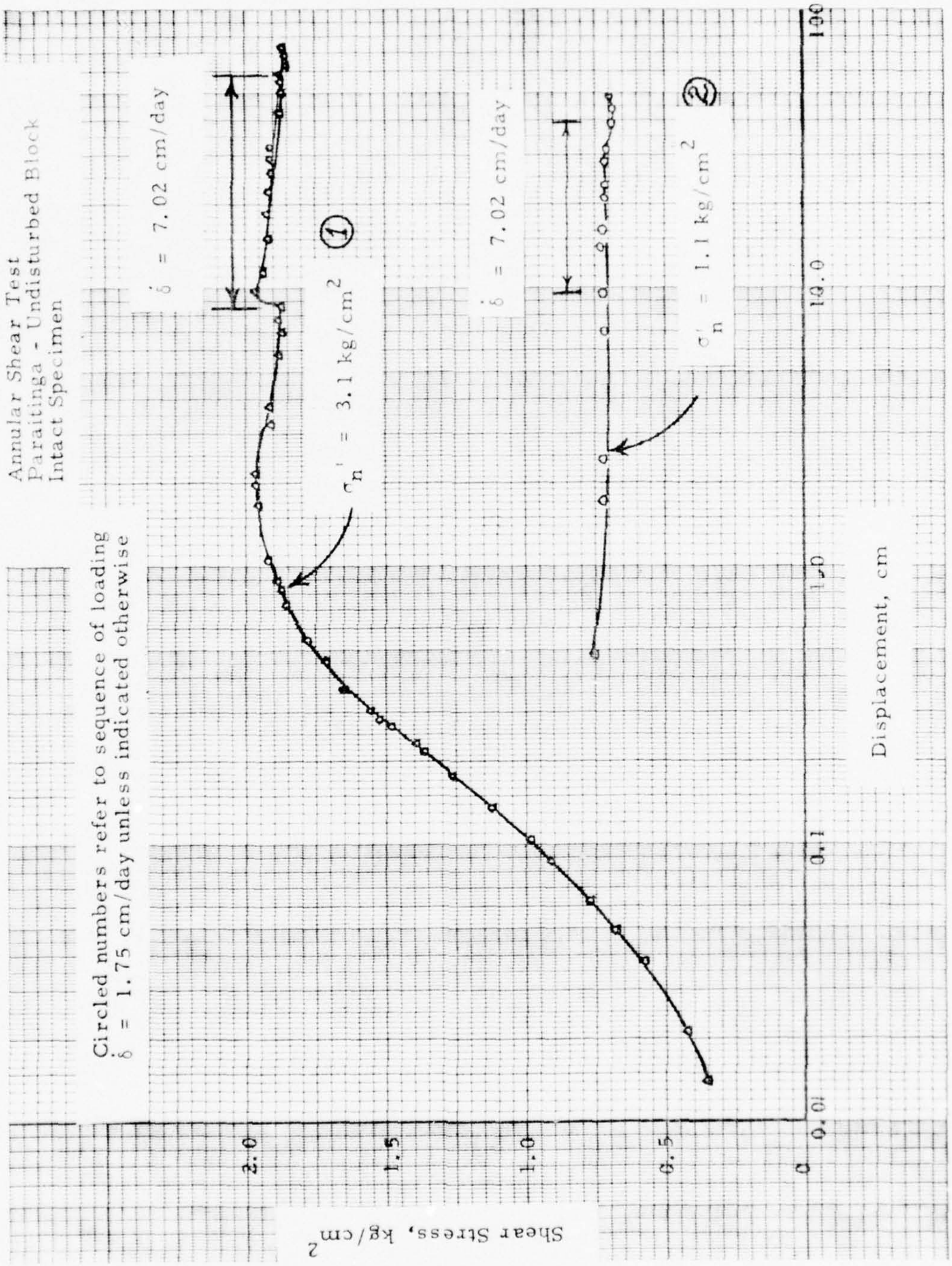
* Residual strength for a given normal load, taken at slowest displacement rate at greatest cumulative amount of displacement.

** Not cumulative.

Table 2 (continued)

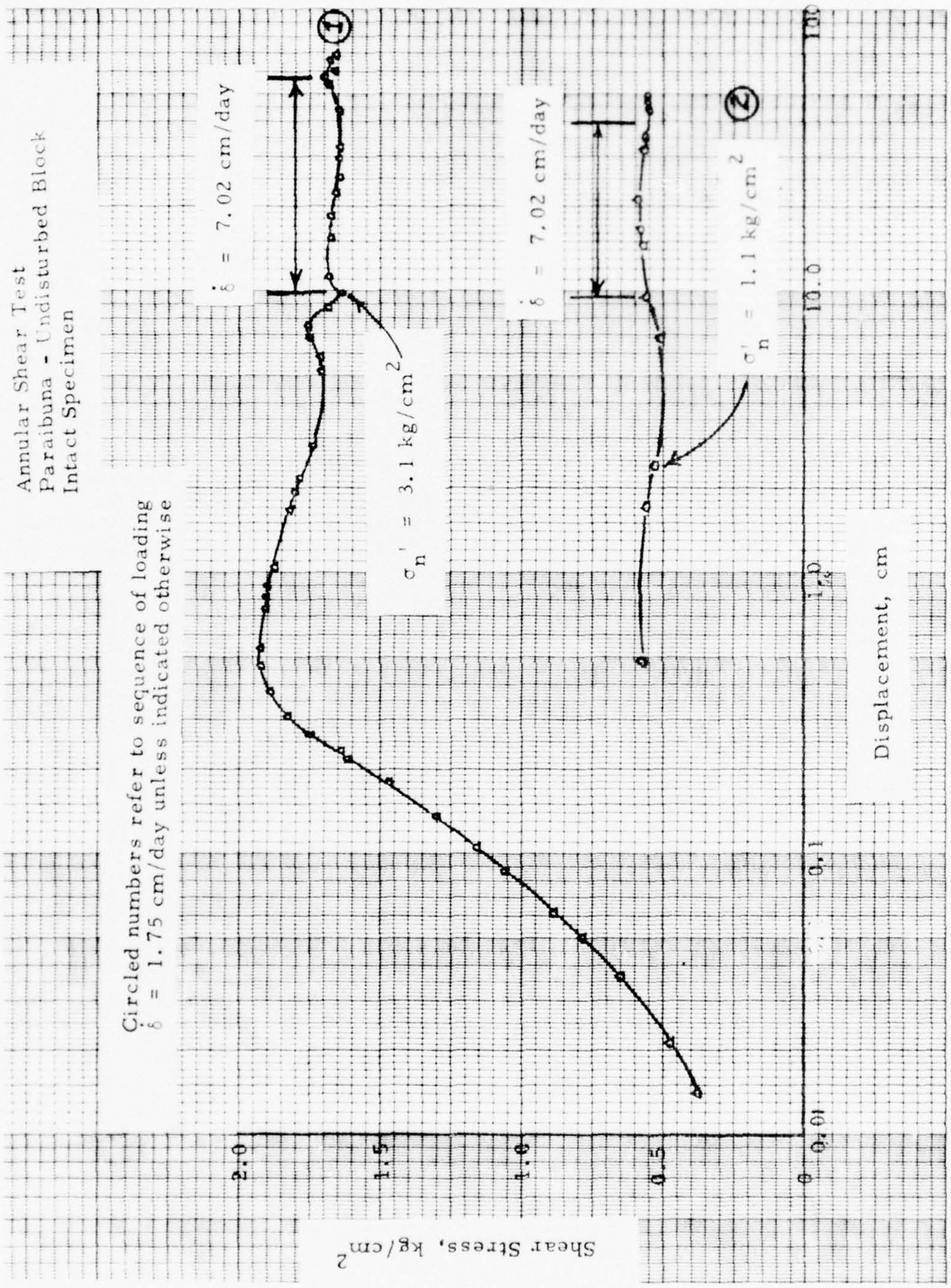
Sample Description	Normal Stress kg/cm^2	Rate of Displacement cm/day	Residual Shear Strength ϕ'_r, deg	Displacement per Stage Required to Achieve ϕ'_r, cm
Paraitinga, block sample, densely compacted, 106.8 pcf	1.1	1.75	33.8	15.6
	1.1	7.02	32.3	35.8
	1.1	1.75	32.4*	2.7
	3.1	1.75	30.8	13.7
	3.1	7.02	29.8	79.9
	3.1	1.75	29.6*	6.4
	9.1	1.75	28.1	23.7
	9.1	7.02	28.1	21.2
	9.1	1.75	27.7*	28.5
Paraibuna, block sample, densely compacted, 108.9 pcf	1.1	1.75	28.3	38.2
	1.1	7.02	28.1	14.0
	1.1	1.75	28.5*	1.7
	3.1	1.75	29.6	15.5
	3.1	7.02	28.6	52.7
	3.1	1.75	28.4*	8.4
	9.1	1.75	27.9	15.1
	9.1	7.02	27.4	44.3
	9.1	1.75	27.1*	2.3

Appendix A: Shear Strength-Shear Displacement and Vertical Displacement-Shear Displacement Curves



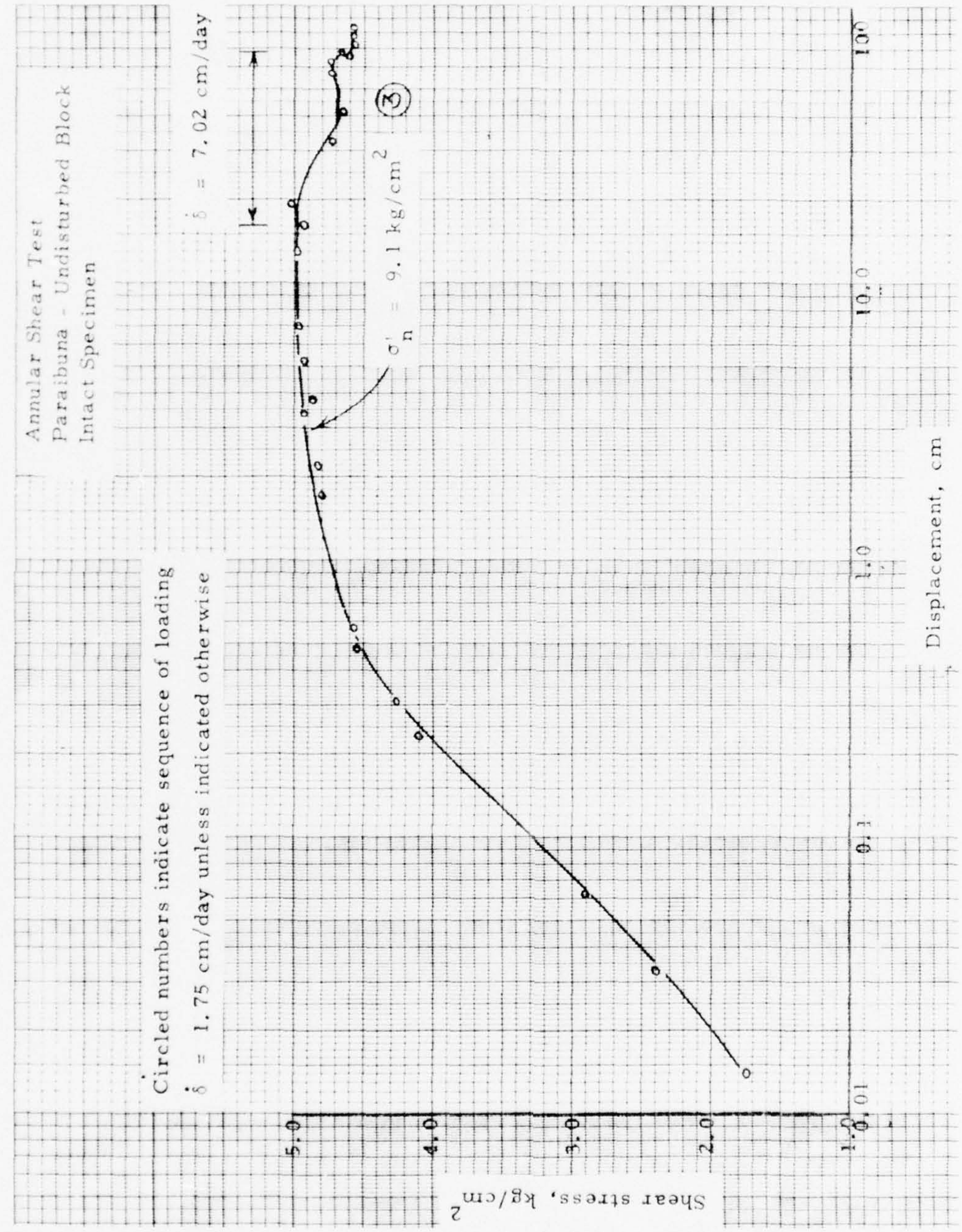
Annular Shear Test
Paraitinga - Undisturbed Block
Intact Specimen
Circled numbers refer to sequence of loading
$\dot{\delta}$ = 1.75 cm/day unless indicated otherwise
$\dot{\delta}$ = 7.02 cm/day
σ_n' = 3.1 kg/cm^2
1
$\dot{\delta}$ = 7.02 cm/day
σ_n' = 1.1 kg/cm^2
2
Shear Stress, kg/cm^2
Displacement, cm
0
0.5
1.0
1.5
2.0
0.01
0.1
1.0
10.0
100

Fig. A1



Annular Shear Test
Paraibuna - Undisturbed Block
Intact Specimen
Circled numbers refer to sequence of loading
$\dot{\delta}$ = 1.75 cm/day unless indicated otherwise
$\dot{\delta}$ = 7.02 cm/day
$\sigma_n{}'$ = 3.1 kg/cm^2
$\dot{\delta}$ = 7.02 cm/day
σ'_n = 1.1 kg/cm^2
1
2
2.0
1.5
1.0
0.5
0
0.01
0.1
1.0
10.0
100
Shear Stress, kg/cm^2
Displacement, cm

Fig. A2



Annular Shear Test
Paraibuna - Undisturbed Block
Intact Specimen
Circled numbers indicate sequence of loading
$\dot{\delta}$ = 1.75 cm/day unless indicated otherwise
$\dot{\delta}$ = 7.02 cm/day
σ'_n = 9.1 kg/cm^2
3
Shear stress, kg/cm^2
5.0
4.0
3.0
2.0
1.0
0.01
0.1
1.0
10.0
100
Displacement, cm

Fig. A3

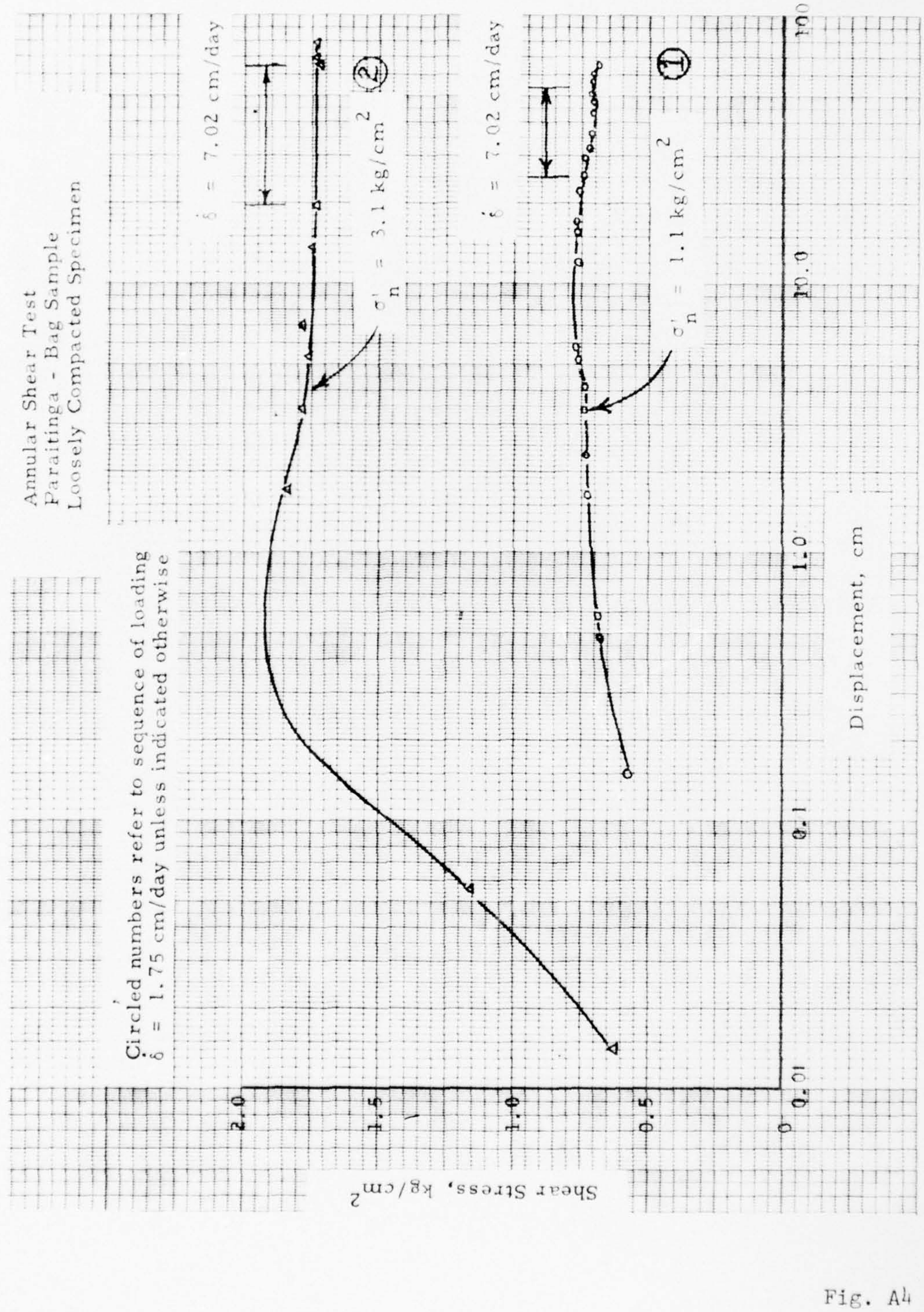

Annular Shear Test
Paraitinga - Bag Sample
Loosely Compacted Specimen
Circled numbers refer to sequence of loading
$\dot{\delta}$ = 1.75 cm/day unless indicated otherwise
$\dot{\delta}$ = 7.02 cm/day
σ'_n = 3.1 kg/cm^2
2
$\dot{\delta}$ = 7.02 cm/day
σ'_n = 1.1 kg/cm^2
1
Shear Stress, kg/cm^2
2.0
1.5
1.0
0.5
0
0.01
0.1
1.0
10.0
100
Displacement, cm

Fig. A4

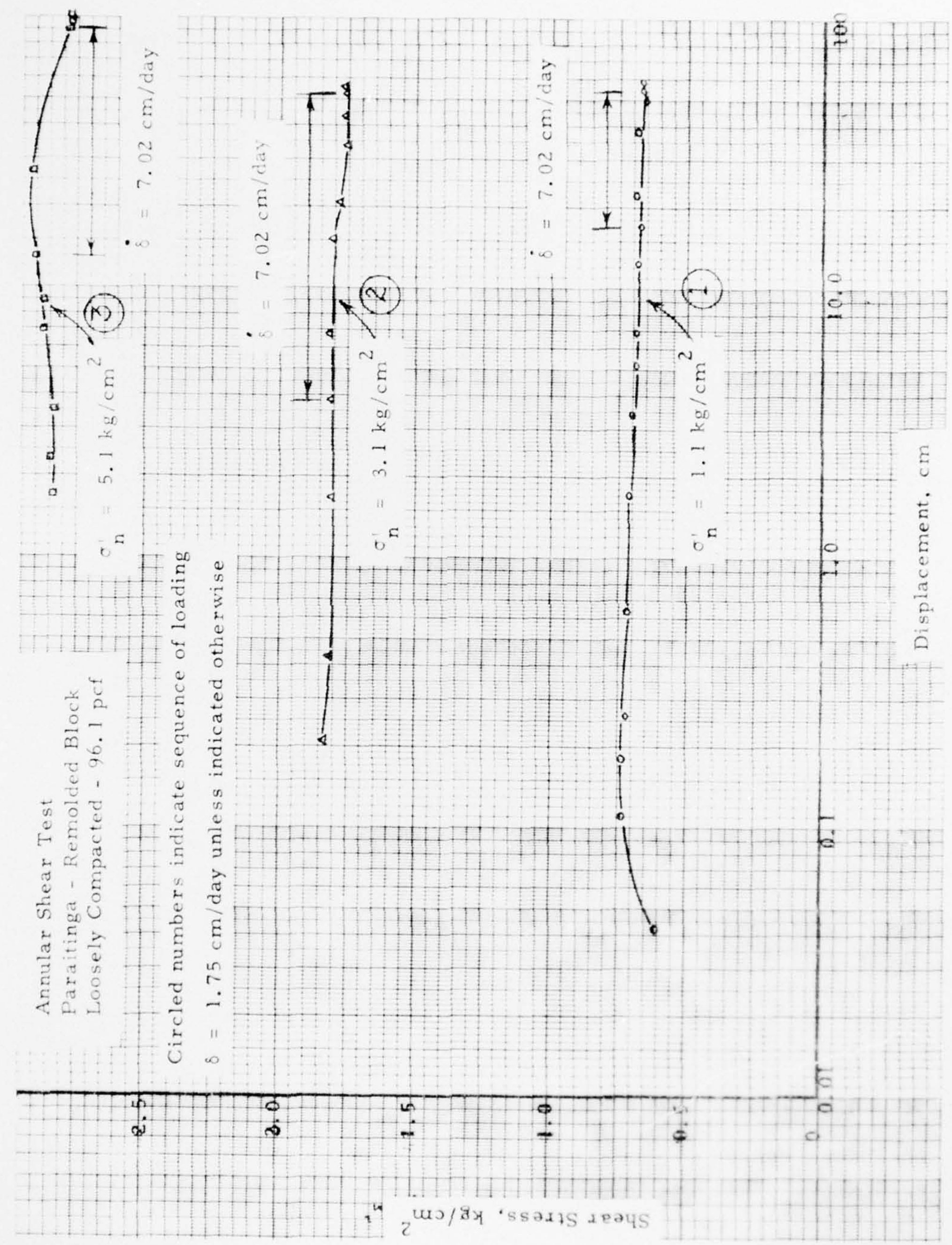

Annular Shear Test
Paraitinga - Remolded Block
Loosely Compacted - 96.1 pcf
Circled numbers indicate sequence of loading
$\dot{\delta}$ = 1.75 cm/day unless indicated otherwise
σ'_n = 5.1 kg/cm^2
$\dot{\delta}$ = 7.02 cm/day
3
σ'_n = 3.1 kg/cm^2
$\dot{\delta}$ = 7.02 cm/day
2
σ'_n = 1.1 kg/cm^2
$\dot{\delta}$ = 7.02 cm/day
1
Shear Stress, kg/cm^2
0
0.5
1.0
1.5
2.0
2.5
0.01
0.1
1.0
10.0
100
Displacement, cm

Fig. A5

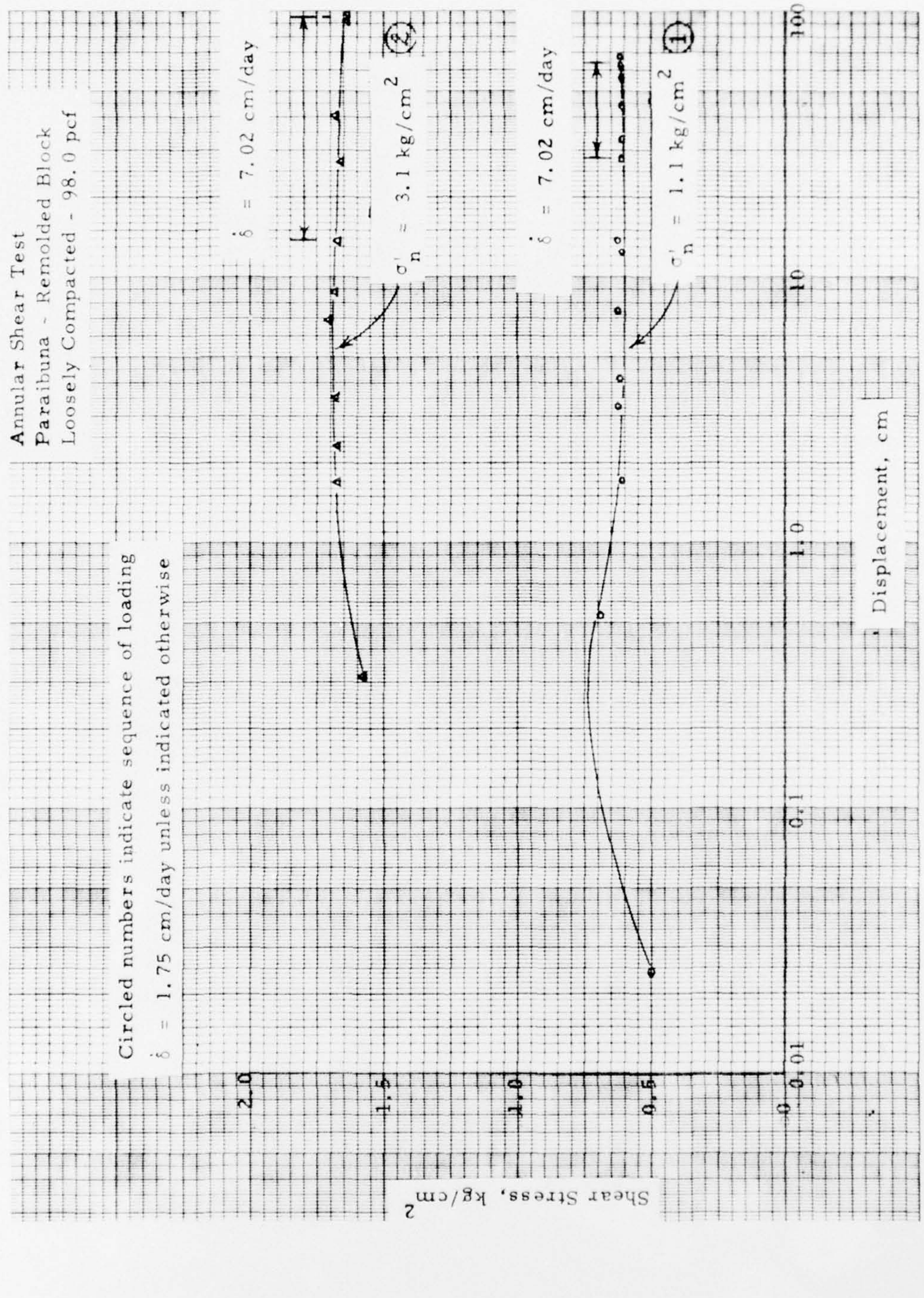

Annular Shear Test
Paraibuna - Remolded Block
Loosely Compacted - 98.0 pcf
Circled numbers indicate sequence of loading
δ̇ = 1.75 cm/day unless indicated otherwise
δ̇ = 7.02 cm/day
σ'n = 3.1 kg/cm2
2
δ̇ = 7.02 cm/day
σ'n = 1.1 kg/cm2
1
Shear Stress, kg/cm2
2.0
1.5
1.0
0.5
0
0.01
0.1
1.0
10
100
Displacement, cm

Fig. A6

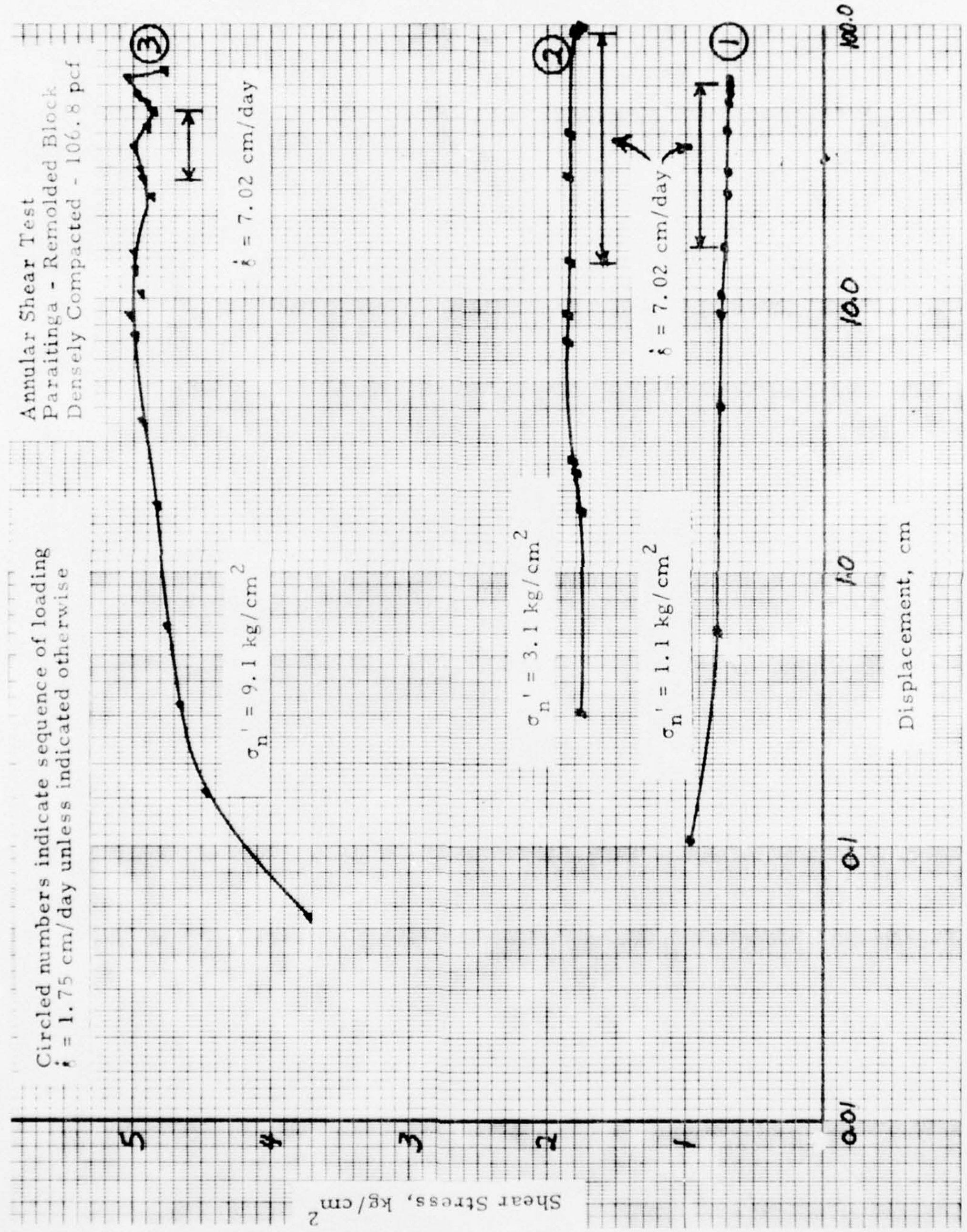

Annular Shear Test
Paraitinga - Remolded Block
Densely Compacted - 106.8 pcf
Circled numbers indicate sequence of loading
$\dot{\delta}$ = 1.75 cm/day unless indicated otherwise
σ_n' = 9.1 kg/cm^2
σ_n' = 3.1 kg/cm^2
σ_n' = 1.1 kg/cm^2
$\dot{\delta}$ = 7.02 cm/day
$\dot{\delta}$ = 7.02 cm/day
1
2
3
Shear Stress, kg/cm^2
5
4
3
2
1
0.01
0.1
1.0
10.0
100.0
Displacement, cm

Fig. A7

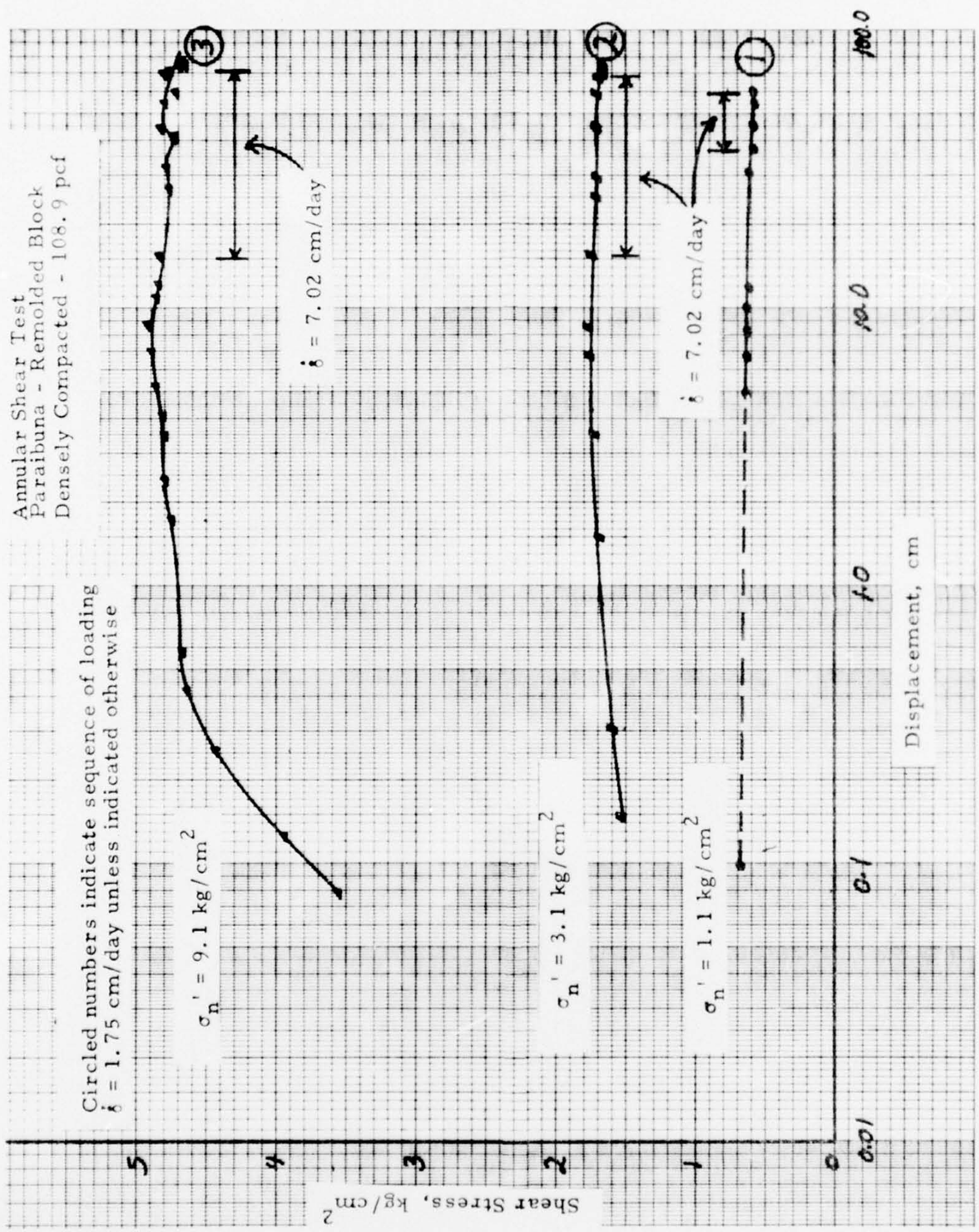

Annular Shear Test
Paraibuna - Remolded Block
Densely Compacted - 108.9 pcf
Circled numbers indicate sequence of loading
$\dot{\delta}$ = 1.75 cm/day unless indicated otherwise
σ_n' = 9.1 kg/cm^2
σ_n' = 3.1 kg/cm^2
σ_n' = 1.1 kg/cm^2
$\dot{\delta}$ = 7.02 cm/day
$\dot{\delta}$ = 7.02 cm/day
3
2
1
Shear Stress, kg/cm^2
0
1
2
3
4
5
Displacement, cm
0.01
0.1
1.0
10.0
100.0

Fig. A8

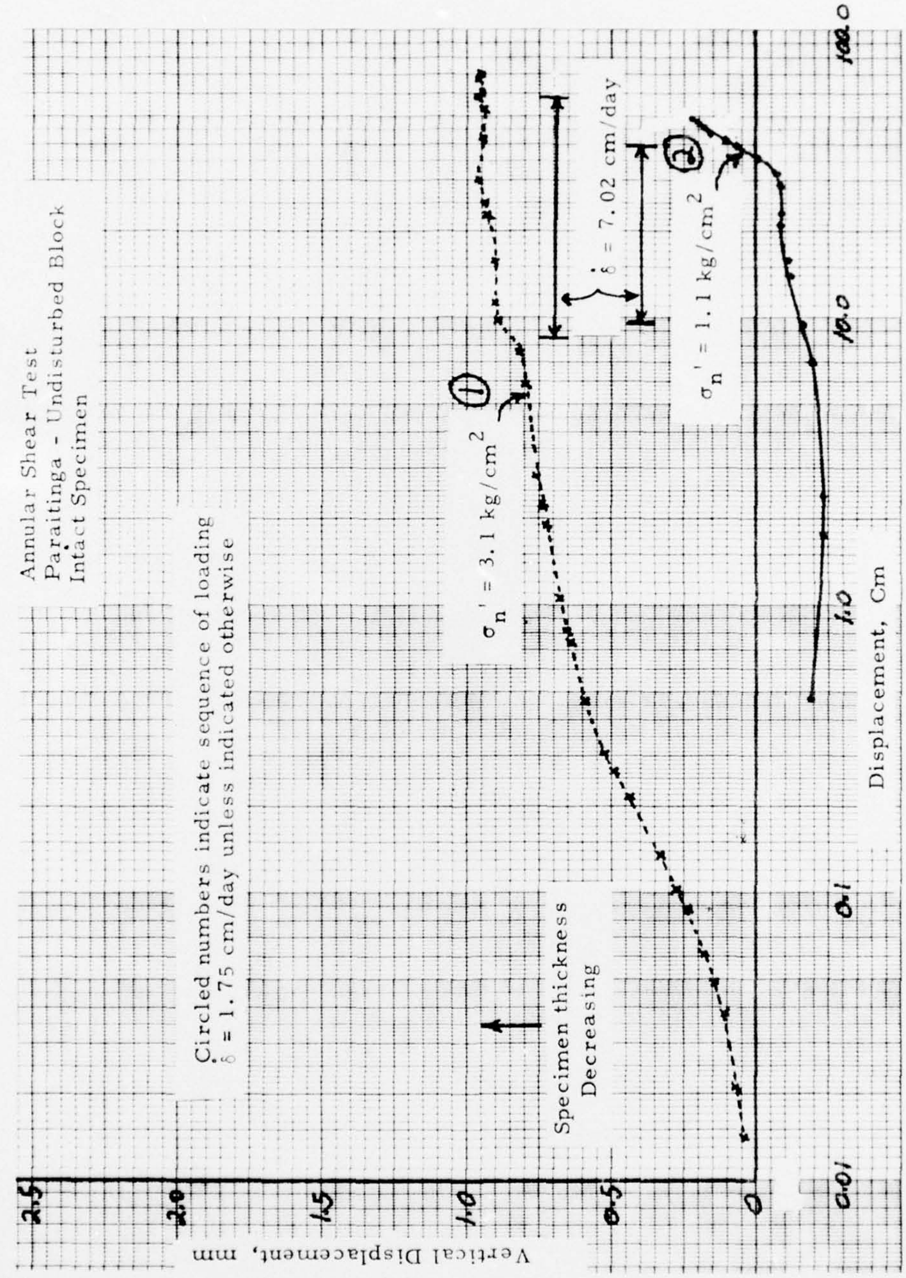
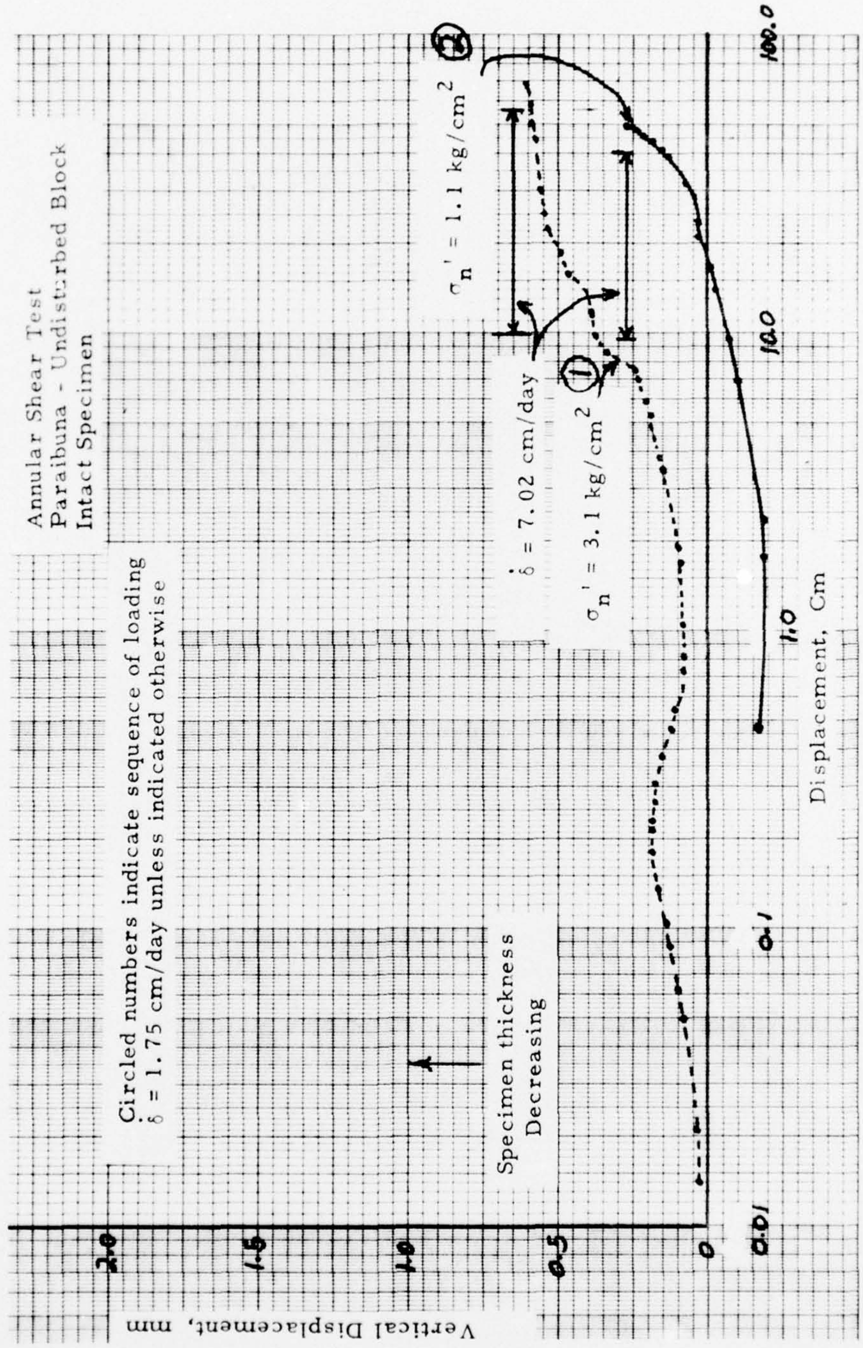
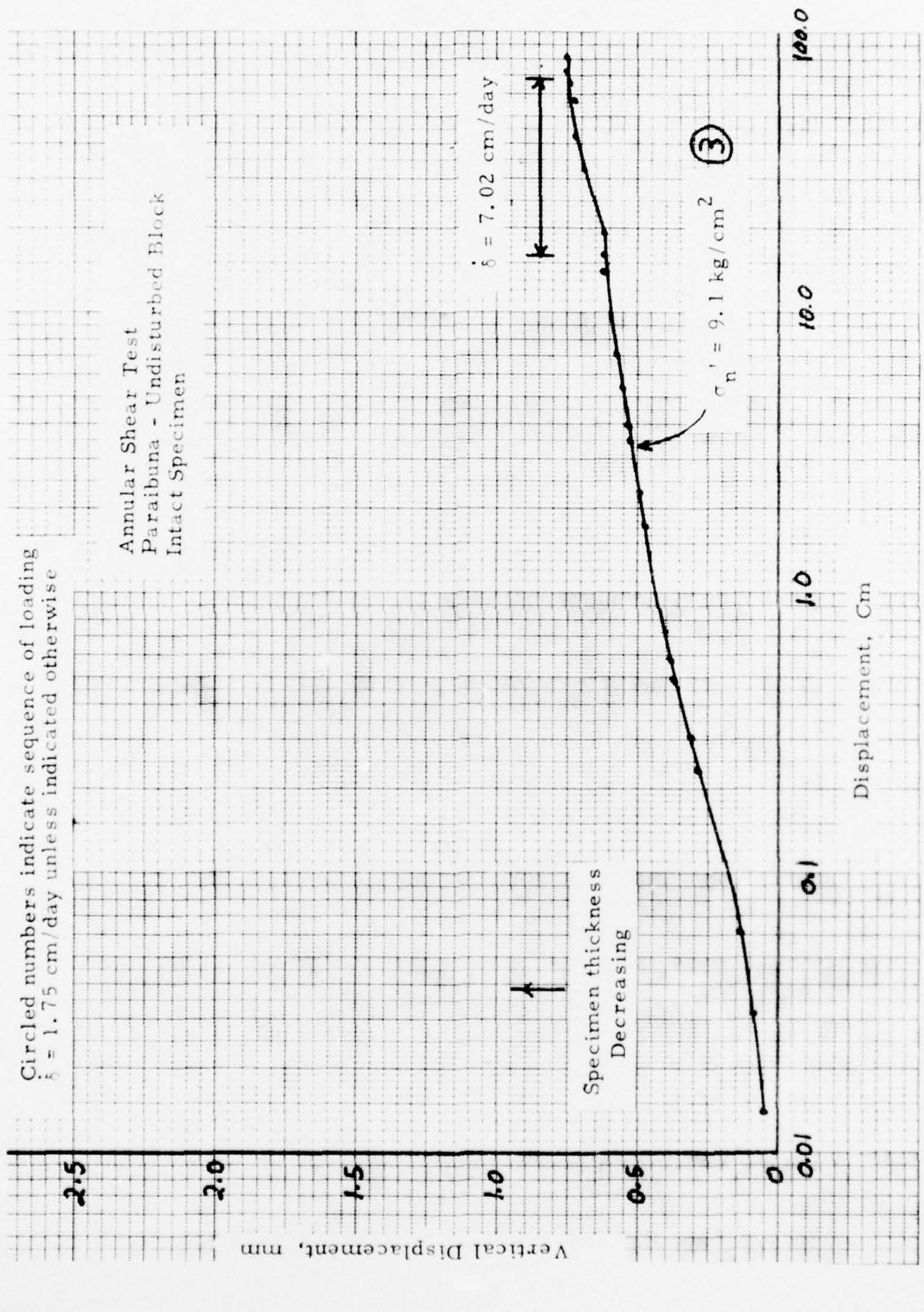

Annular Shear Test
Paraitinga - Undisturbed Block
Intact Specimen
Circled numbers indicate sequence of loading
$\dot{\delta}$ = 1.75 cm/day unless indicated otherwise
Specimen thickness
Decreasing
$\sigma_n{}'$ = 3.1 kg/cm^2
1
$\dot{\delta}$ = 7.02 cm/day
$\sigma_n{}'$ = 1.1 kg/cm^2
2
Vertical Displacement, mm
2.5
2.0
1.5
1.0
0.5
0
0.01
0.1
1.0
10.0
100.0
Displacement, Cm

Fig. A9



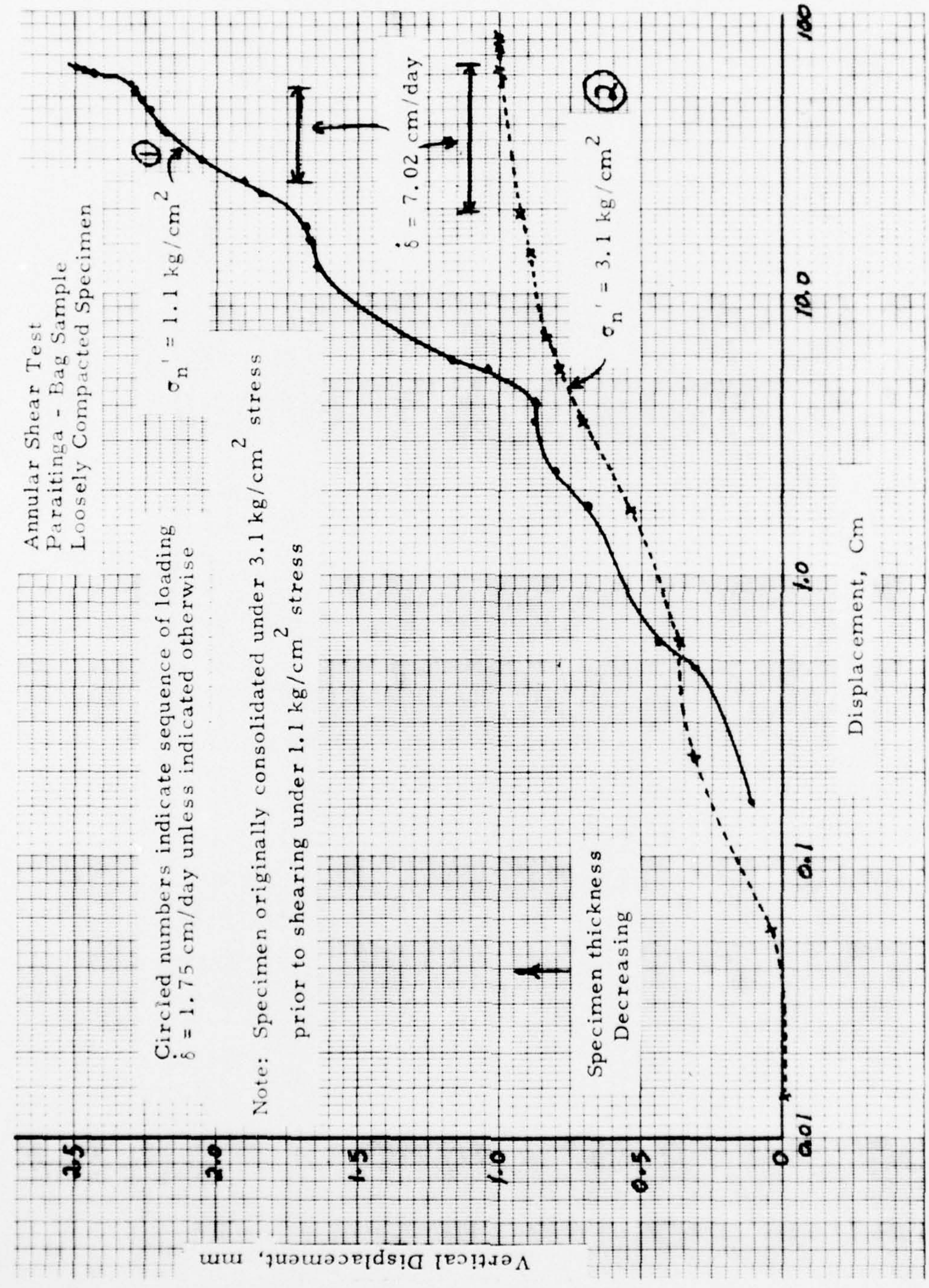
Annular Shear Test
Paraibuna - Undisturbed Block
Intact Specimen
Circled numbers indicate sequence of loading
$\dot{\delta}$ = 1.75 cm/day unless indicated otherwise
Specimen thickness
Decreasing
$\dot{\delta}$ = 7.02 cm/day
σ_n' = 3.1 kg/cm^2
σ_n' = 1.1 kg/cm^2
1
2
Vertical Displacement, mm
2.0
1.5
1.0
0.5
0
0.01
0.1
1.0
10.0
100.0
Displacement, Cm

Fig. A10



Circled numbers indicate sequence of loading
$\dot{\delta}$ = 1.75 cm/day unless indicated otherwise
Annular Shear Test
Paraibuna - Undisturbed Block
Intact Specimen
$\dot{\delta}$ = 7.02 cm/day
3
σ_n' = 9.1 kg/cm^2
Specimen thickness
Decreasing
Vertical Displacement, mm
0
0.5
1.0
1.5
2.0
2.5
0.01
0.1
1.0
10.0
100.0
Displacement, Cm

Fig. A11



Annular Shear Test
Paraitinga - Bag Sample
Loosely Compacted Specimen
Circled numbers indicate sequence of loading
$\dot{\delta}$ = 1.75 cm/day unless indicated otherwise
σ_n' = 1.1 kg/cm^2
1
Note: Specimen originally consolidated under 3.1 kg/cm^2 stress
prior to shearing under 1.1 kg/cm^2 stress
$\dot{\delta}$ = 7.02 cm/day
σ_n' = 3.1 kg/cm^2
2
Specimen thickness
Decreasing
Vertical Displacement, mm
Displacement, Cm
2.5
2.0
1.5
1.0
0.5
0
0.01
0.1
1.0
10.0
100

Fig. A12

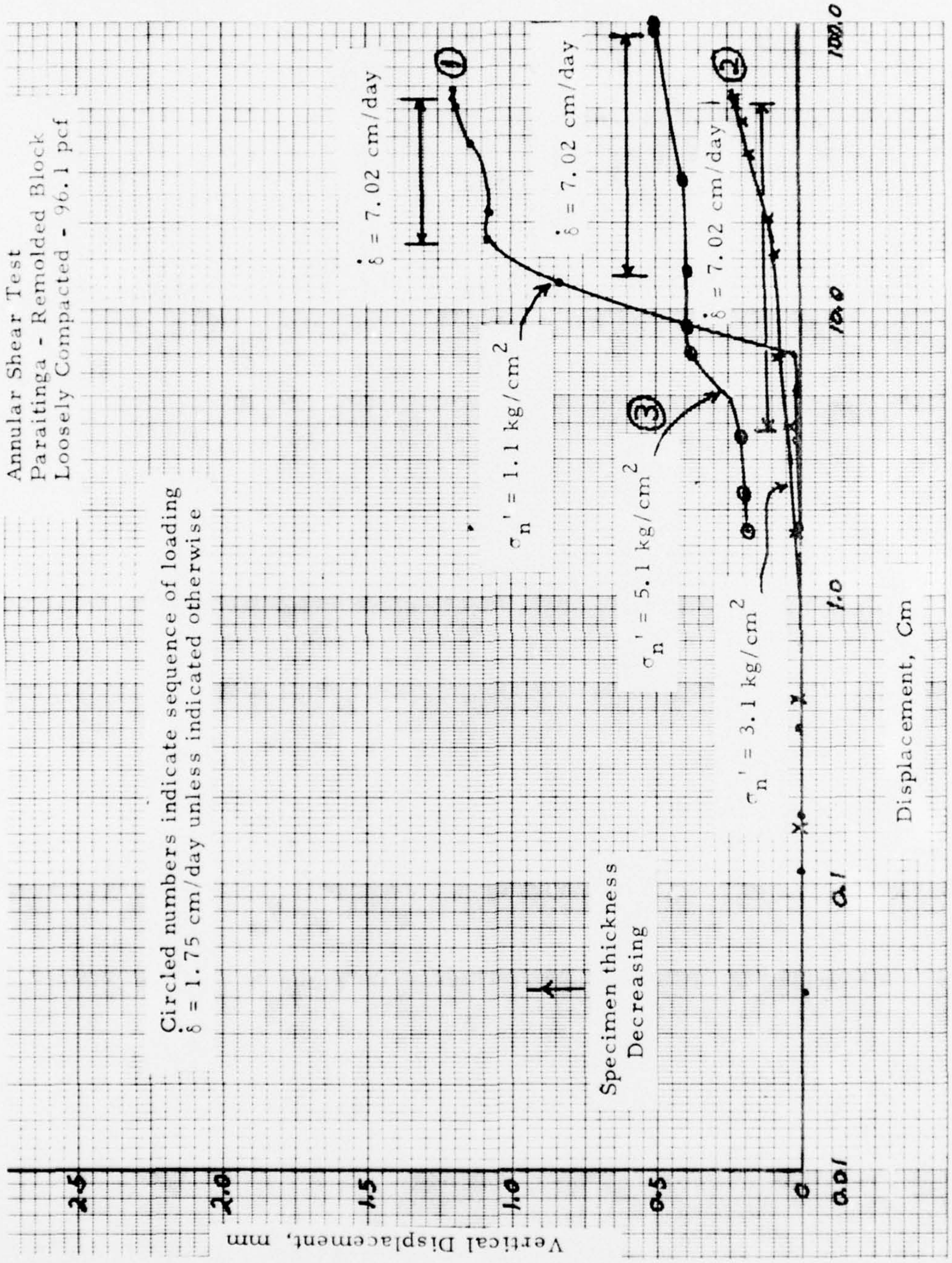
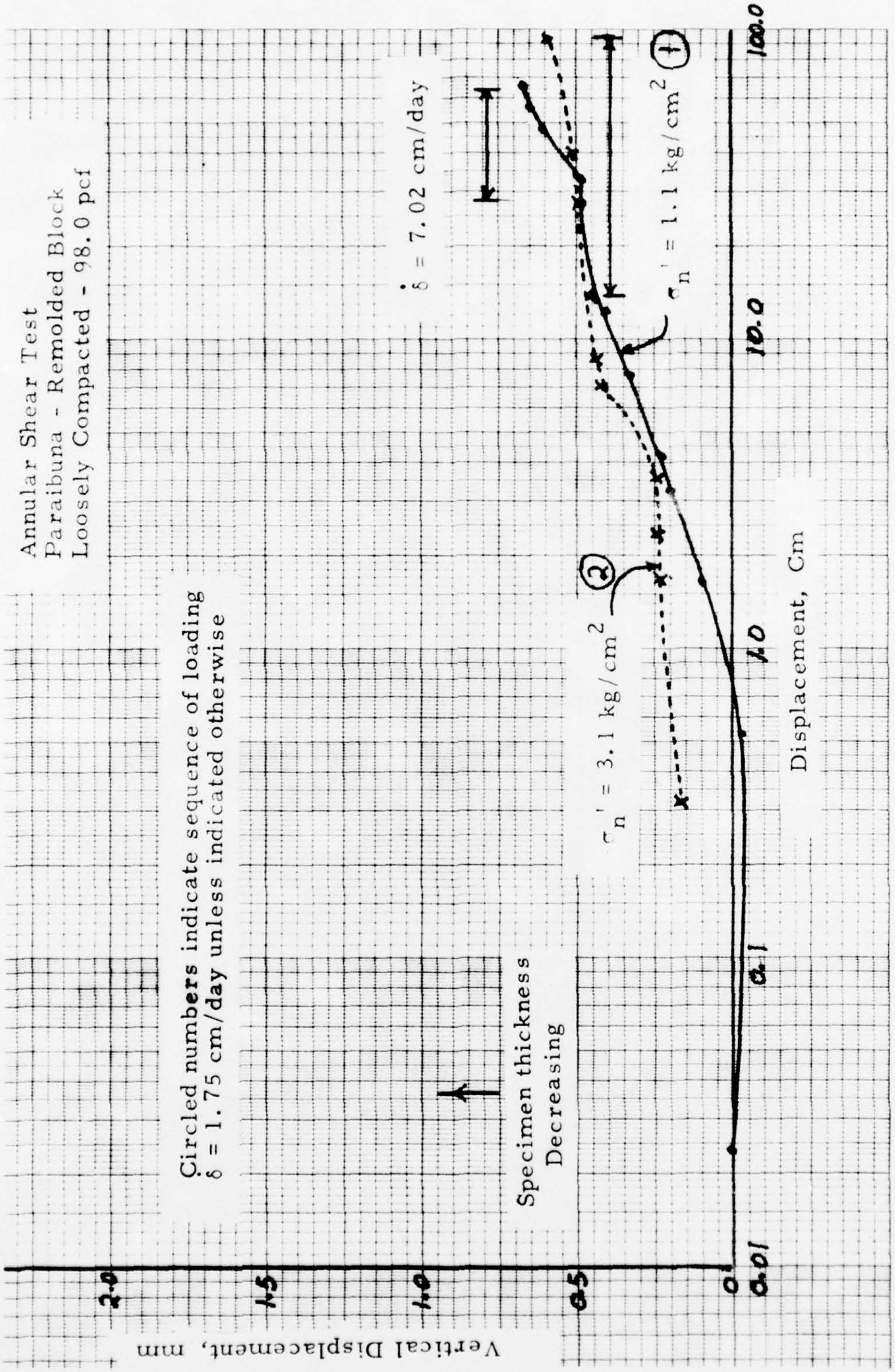
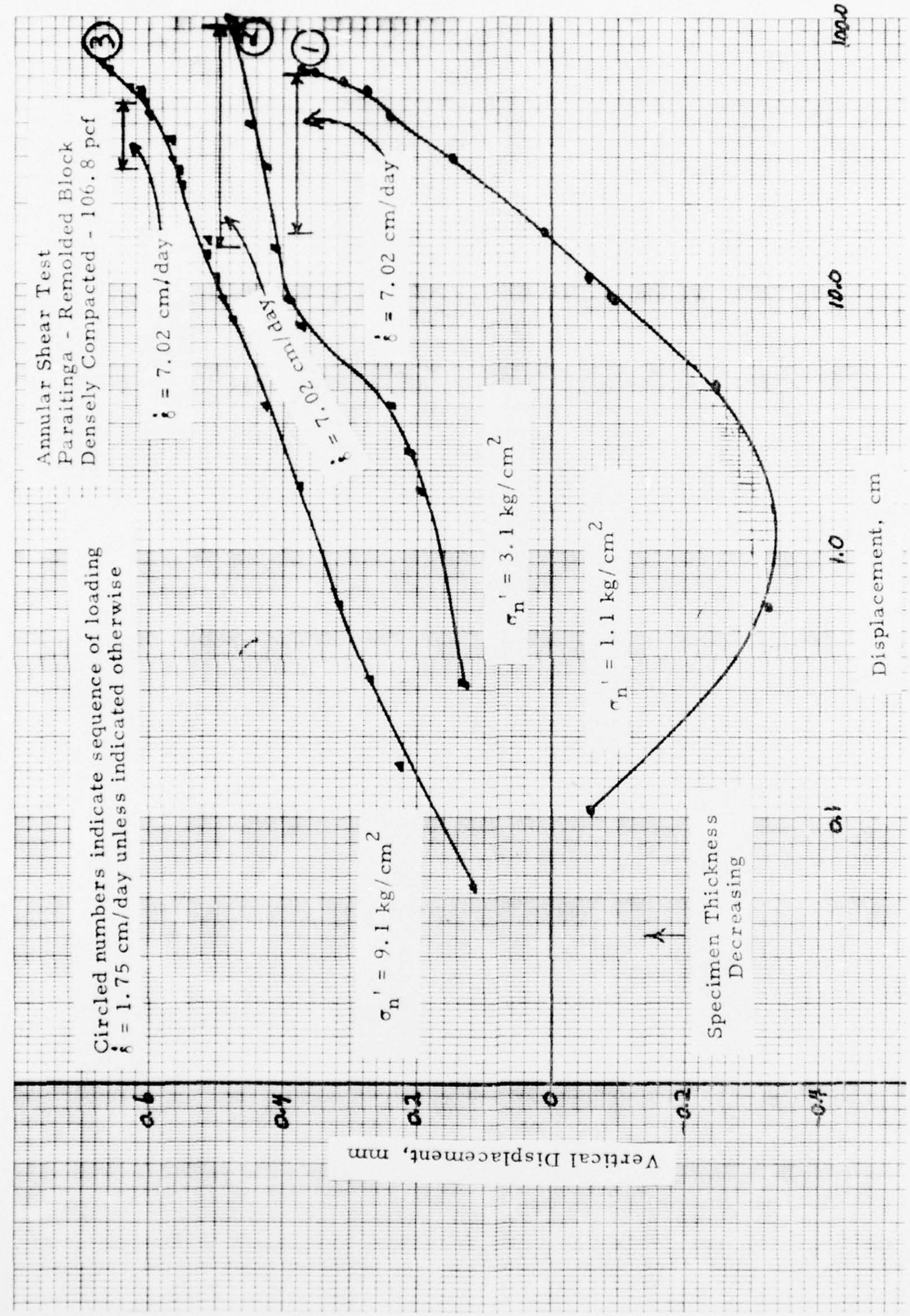

Annular Shear Test
Paraitinga - Remolded Block
Loosely Compacted - 96.1 pcf
Circled numbers indicate sequence of loading
$\dot{\delta}$ = 1.75 cm/day unless indicated otherwise
Specimen thickness
Decreasing
$\dot{\delta}$ = 7.02 cm/day
$\dot{\delta}$ = 7.02 cm/day
$\dot{\delta}$ = 7.02 cm/day
σ_n' = 1.1 kg/cm^2
σ_n' = 5.1 kg/cm^2
σ_n' = 3.1 kg/cm^2
1
2
3
Vertical Displacement, mm
Displacement, Cm
2.5
2.0
1.5
1.0
0.5
0
0.01
0.1
1.0
10.0
100.0

Fig. A13



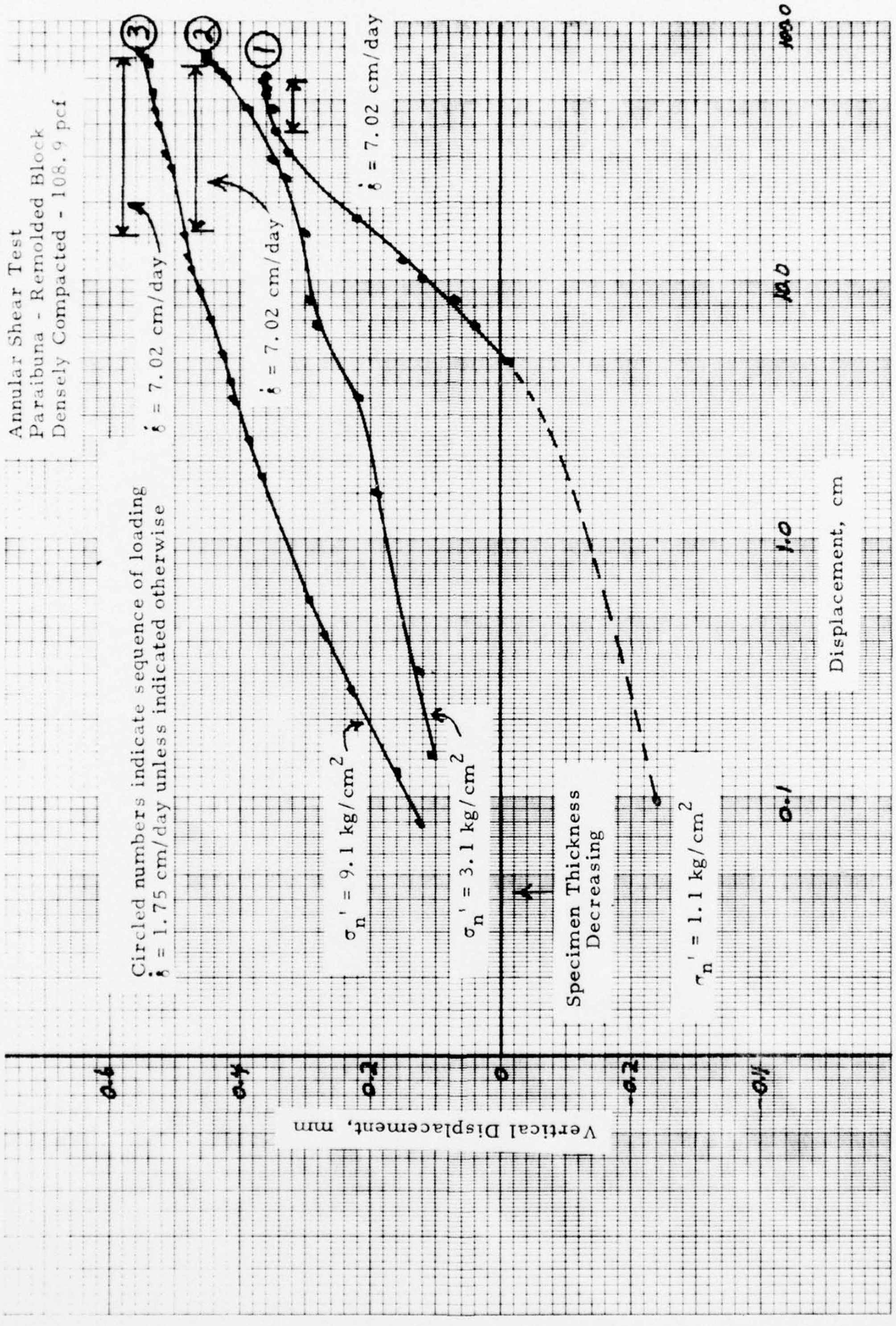
Annular Shear Test
Paraibuna - Remolded Block
Loosely Compacted - 98.0 pcf
Circled numbers indicate sequence of loading
$\dot{\delta}$ = 1.75 cm/day unless indicated otherwise
$\dot{\delta}$ = 7.02 cm/day
Specimen thickness
Decreasing
σ_n' = 3.1 kg/cm^2
2
σ_n' = 1.1 kg/cm^2
1
Vertical Displacement, mm
Displacement, Cm
2.0
1.5
1.0
0.5
0
0.01
0.1
1.0
10.0
100.0

Fig. A14



Annular Shear Test
Paraitinga - Remolded Block
Densely Compacted - 106.8 pcf
Circled numbers indicate sequence of loading
$\dot{\delta}$ = 1.75 cm/day unless indicated otherwise
$\dot{\delta}$ = 7.02 cm/day
$\dot{\delta}$ = 7.02 cm/day
$\dot{\delta}$ = 7.02 cm/day
$\sigma_n{}'$ = 9.1 kg/cm^2
$\sigma_n{}'$ = 3.1 kg/cm^2
$\sigma_n{}'$ = 1.1 kg/cm^2
Specimen Thickness Decreasing
Vertical Displacement, mm
Displacement, cm
0.6
0.4
0.2
0
-0.2
-0.4
0.1
1.0
10.0
100.0
1
2
3

Fig. A15



Annular Shear Test
Paraibuna - Remolded Block
Densely Compacted - 108.9 pcf
Circled numbers indicate sequence of loading
$\dot{\delta}$ = 1.75 cm/day unless indicated otherwise
$\dot{\delta}$ = 7.02 cm/day
$\dot{\delta}$ = 7.02 cm/day
$\dot{\delta}$ = 7.02 cm/day
1
2
3
$\sigma_n{}'$ = 9.1 kg/cm^2
$\sigma_n{}'$ = 3.1 kg/cm^2
$\sigma_n{}'$ = 1.1 kg/cm^2
Specimen Thickness Decreasing
Vertical Displacement, mm
0.6
0.4
0.2
0
-0.2
-0.4
Displacement, cm
0.1
1.0
10.0
100.0

Fig. A16

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13. ABSTRACT

The residual strengths of two micaceous soils from Paraitinga and Paraibuna damsites, Brazil, were determined using multistage annular shear tests. Tests were conducted under three normal loads, 1.1, 3.1, and 9.1 kg/cm^2. Test specimens were densely or loosely compacted (i.e., 100 and 90 ~~percent~~ % of maximum standard density) prior to shear.

Test results show that the initial specimen density has no effect on the residual shear strength ϕ'_r values. In the case of both materials, ϕ'_r was practically equal for both the densely and loosely compacted specimens. The Paraitinga material exhibited a slightly higher ϕ'_r value than the Paraibuna material, 28.0 versus 26.7 deg, respectively.

Phi sub r prime

DD FORM 1473, 1 NOV 65 — REPLACES DD FORM 1473, 1 JAN 64, WHICH IS OBSOLETE FOR ARMY USE.

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	ROLE	WT	ROLE	WT	ROLE	WT
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